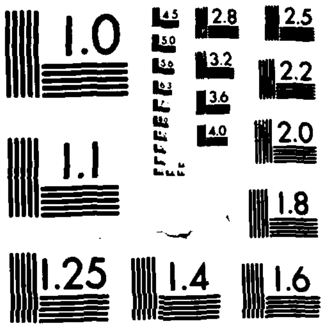
AD-A171 992 EVALUATION OF MICROCOMPUTER-BASED OPERATION AND MAINTENANCE MANAGEMENT SY..(U) CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL C P POON ET AL. 1/1

UNCLASSIFIED JUL 86 CERL-TR-N-86/18 F/G 5/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

US Army Corps of Engineers
Construction Engineering Research Laboratory

USA-CERL

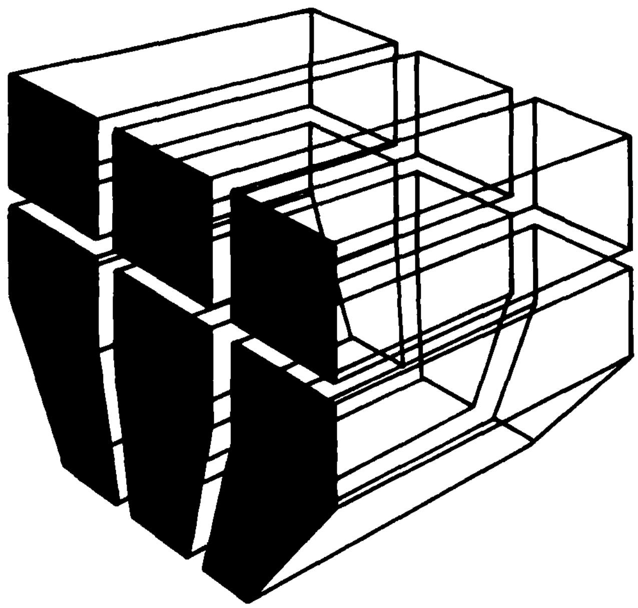
TECHNICAL REPORT N-86/18
Water/Wastewater Plant Automation
July 1986

Evaluation of Microcomputer-Based Operation and Maintenance Management Systems for Army Water/Wastewater Treatment Plant Operation

by
C. P. C. Poon
J. T. Bandy
T. M. Prakash
M. T. Shrake
R. M. Marlatt
L. E. Lang

Poor data management and inadequate preventive maintenance are considered significant causes for some Department of Defense wastewater treatment plants failing to meet their National Pollutant Discharge Elimination System permit requirements. Microcomputer-based operation and maintenance (O&M) management systems have been successfully implemented in private-sector wastewater treatment plants and can provide similar plants at Army installations with improved management of process control parameters, trend analysis to simulate and control processes, automatic report preparation, and better preventive maintenance management.

This report provides a detailed evaluation of microcomputer-based O&M management systems for use in Army water/wastewater treatment plant operation. In particular, capabilities of various microcomputer-based process management and maintenance systems were compared to determine how this technology could best be exploited in Army applications. Field demonstrations of microcomputer technologies for sewage treatment plants were performed at Fort Sill, OK, and Fort Meade, MD, and the essentials of an effective preventive maintenance program outlined. Guidance for selection, procurement, and implementation of microcomputer-based O&M management systems at Army water/wastewater treatment plants were then chosen based on the analysis.



Approved for public release; distribution unlimited.

A171 992

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CERL TR N-86/18	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Evaluation of Microcomputer-Based Operation and Maintenance Management Systems for Army Water/Wastewater Treatment Plant Operation	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): C. P. C. Poon, J. T. Bandy, T. M. Prakash, M. T. Shrake, R. M. Marlatt, L. E. Lang	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Construction Engr Research Laboratory, P.O. Box 4005, Champaign, IL 61820-1305	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: FTAT
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: July 1986
	13. NUMBER OF PAGES: 94
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service
Springfield, VA 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

wastewater
waste treatment
microcomputers
maintenance management

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Poor data management and inadequate preventive maintenance are considered significant causes for some Department of Defense wastewater treatment plants failing to meet their National Pollutant Discharge Elimination System permit requirements. Microcomputer-based operation and maintenance (O&M) management systems have been successfully implemented in private-sector wastewater treatment plants and can provide similar plants at Army installations with improved management of process control parameters, trend analysis to simulate and control processes, automatic report preparation, and better preventive maintenance management. (cont'd)

BLOCK 20. (Cont'd)

This report provides a detailed evaluation of microcomputer-based O&M management systems for use in Army water/wastewater treatment plant operation. In particular, capabilities of various microcomputer-based process management and maintenance systems were compared to determine how this technology could best be exploited in Army applications. Field demonstrations of microcomputer technologies for sewage treatment plants were performed at Fort Sill, OK, and Fort Meade, MD, and the essentials of an effective preventive maintenance program outlined. Guidance for selection, procurement, and implementation of microcomputer-based O&M management systems at Army water/wastewater treatment plants were then chosen based on the analysis.

FOREWORD

This study was conducted for the Office of the Assistant Chief of Engineers (OACE), under Project Facilities Technology Applications Test (FTAT)-Env. Quality; Work Unit, "Water/Wastewater Plant Automation." The work was performed by the University of Rhode Island for the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USA-CERL), under Indefinite Delivery Contract DACW88-84-d-0004, Line Item 1. The applicable STO is 82-7/23. The OACE Technical Monitor was Mr. T. Wash, DAEN-ZCF-U.

Special appreciation is extended to the personnel at Forts Sill and Meade who worked on the microcomputer systems; to C. P. C. Poon and M. T. Shrake of the University of Rhode Island for their contributions to the study; and to Dr. Ed Smith, Team Leader, Water Quality Management Team, USA-CERL.

Dr. R. K. Jain is Chief of USA-CERL-EN. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

CONTENTS (Cont'd)

FIGURES

TABLES

EVALUATION OF MICROCOMPUTER-BASED OPERATION AND MAINTENANCE MANAGEMENT SYSTEMS FOR ARMY WATER/WASTEWATER TREATMENT PLANT OPERATION

1 INTRODUCTION

Background

A recent U.S. General Accounting Office report[1] identified poor data management and inadequate preventive maintenance as significant reasons that Department of Defense (DOD) wastewater treatment plants are failing to meet their permitted discharge limits. In contrast, during the past few years the private sector has begun using microcomputer-based control systems, process data management systems, and computerized trend analysis. These simulate and control treatment processes and reduce the administrative burden of reporting plant performance to various regulatory agencies by generating hard-copy reports, compiling data, and calculating averages and parameters.

Some of the successfully implemented computer applications are:

1. Management of process control parameters

2. Trend analysis

3. Automatic report preparation

4. Preventive maintenance management, consisting of
   a. Work order tracking
   b. Equipment information
   c. Scheduling
   d. Management reporting.

It is likely that microcomputer-based operation and maintenance (O&M) management systems can provide similar benefits at Army wastewater treatment plants.

The use of microcomputers at wastewater treatment plants can also provide several other benefits, such as minimizing energy use and reducing O&M costs in general. Effective computerized maintenance scheduling and tracking can reduce equipment repair cost and optimize use of personnel. Improved supply inventory can minimize downtime. Operational trend analysis can identify problems early so they can be corrected before they become critical. However, before these benefits can be realized, Army installations must first determine which of the many available systems will best meet their needs.

PREVIOUS PAGE IS BLANK

[1] *DOD Can Make Further Progress in Controlling Pollution From Its Sewage Treatment Plants*, GAO/NSIAD-84-5 (U.S. General Accounting Office, February 3, 1984).

Objective

The objectives of this study were to (1) determine how the recently developed microcomputer-based process and maintenance management systems can best be exploited at Army water/wastewater treatment plants and (2) develop guidance to assist Army installations considering adoption of this new technology.

Approach

Information regarding commercially available microcomputer-based O&M management systems was collected and their applications in private sector water/wastewater treatment plants identified. Army wastewater treatment plants were surveyed to determine the potential for using microcomputer-based O&M systems. A detailed analysis of the commercially available systems was performed, and systems with features most applicable to Army water/wastewater treatment plants were identified. Two systems were field tested: one at Fort Sill, OK, and one at Fort Meade, MD. Based on the information collected, guidelines were established for Army-wide implementation of the microcomputer-based O&M systems in wastewater treatment operations.

Mode of Technology Transfer

It is recommended that the information in this report serve as the basis for an Engineer Technical Note (ETN) providing succinct guidance using microcomputer technology in wastewater treatment at Army installations. A videotape is now being made to transfer this information to potential users.

2 OVERVIEW OF MICROCOMPUTER APPLICATIONS IN WATER AND WASTEWATER TREATMENT FACILITIES

The increasing complexity of water and wastewater treatment plants and their strict effluent requirements demand a significant effort by plant personnel, both in operation and maintenance. The complexity of the treatment processes requires careful monitoring and the collection and analysis of much data. The large amount of mechanical and electrical equipment needed to operate a plant requires timely maintenance to reduce breakdowns. Increasing the reliability of equipment to minimize process failure and maintaining the effluent quality required by the regulating agencies are very important functions.

The use of computers to assist treatment plant O&M has gained acceptance in the private sector largely because of improved plant performance, but also because it provides several other benefits, particularly increased personal productivity. This report emphasizes the use of microcomputers to assist wastewater treatment plant O&M management. The same concept and approach also apply to water treatment plants.

Private Sector Experience

A GAO study[2] which investigated the noncompliance problems of the nation's wastewater treatment plants noted that 50 to 75 percent of 242 treatment plants sometimes violated their discharge permits. Among their problems were:

1. Design deficiencies
2. Infiltration/inflow overloads
3. Industrial waste overloads
4. O&M deficiencies.

At the treatment plant level, the supervisor or manager can increase treatment performance by overcoming O&M deficiencies. Only the newer wastewater treatment plants, built with Federal funds, have O&M manuals; however, other efforts to train operators are minimal. Many of the current O&M manuals are general. Although they could be used as guidelines, they are not specific enough to use for running the plants. Many operators are not certified and lack the skills to do their jobs. Thus, properly educating and training treatment plant operators in O&M can increase treatment plant performance levels.

Process Automation

For some time, industries have used process automation with computer control to increase performance reliability and have now introduced it into water and wastewater treatment systems. At least 50 plants in the United States use computerized control

[2] *Costly Wastewater Treatment Plants Fail To Perform as Expected*, GA/CED-81-9 (U.S. General Accounting Office, November 14, 1980).

systems for water treatment processes.[3] The on-line computer controls the treatment process, monitors process variables, triggers alarms, and logs data on the system's operations. Some of these computerized control systems can optimize power demand and chemical dosage, as well as carry out tasks such as mathematical modeling of the treatment processes, executive management programming, and maintenance and inventory control.

Despite the successful application of computer systems for process control automation, the experience of such application in wastewater treatment plants using sophisticated closed-loop monitoring and computer-controlled operation has been poor.

For wastewater treatment, on-line computerized system use is sufficiently reliable for instruments that measure water level, flow, temperature, pressure, speed, weight, position, conductivity, rainfall, turbidity, pH, residual chlorine, free chlorine gas, and free-flammable gases. On the other hand, sludge density meters, sludge blanket level detectors, on-line respirometers, and dissolved oxygen probes require high levels of maintenance. Many plants have found these sensors to be unsuitable for dependable use in automatic systems. A large number of wastewater treatment plants have only a handful of their sensors operating at any one time[4] (for example, a $400 million plant in the northeast with only a few sensors out of thousands operable, a Georgia facility with 20 of 700 points working, a Huntsville plant with one of 40 in operation, and a Washington, D.C., sanitary commission with a 70 percent downtime for its sensors).

Process automation has had only marginal success in improving effluent quality, saving energy, and saving processing chemicals, materials, and equipment. Due to the transient nature of the wastewater flow in treatment systems, problems remain with modeling the processes and designing accurate handling systems.

A performance comparison[5] of 12 wastewater treatment plants using automatic dissolved oxygen control shows varying degrees of success. Moreover, other case histories show reservations about the efficiency of computer control of treatment systems. At New York City's Tallman Island Pollution Control Facility, it appears feasible to use automated systems and remote sensing devices; however, overall computerized control failed to win the confidence of system designers.

The major problem in installing and operating automatic and instrumental controls is the lack of appropriate, reliable sensors. When used in the form of probes or electrodes in wastewater treatment, sensors are subjected to a hostile environment. They become coated and are attacked by chemicals in the flow. Excessive preventive maintenance is required to keep them operating properly. The design of software which can account for real-time, interactive parameters is also inadequate. These two problems are more apparent in wastewater treatment systems than in water treatment systems due to the transient input quantity as well as the quality of and biological activity within the wastewater.

---

[3] G. W. Reid, A. L. Law, and G. P. Chou, *Evaluation and Selection of Reliability and Maintainability of Water/Wastewater Treatment Technology for Military Application*, Final Report, Vol I (University of Oklahoma, August 1982).

[4] A. Pantages, "The Case for Computerization," *Pollution Engineering* (January 1984).

[5] G. W. Reid, A. L. Law, and G. P. Chou.

Computer-Aided O&M

While on-line computerized automatic control is not yet seen as desirable, off-line use of a computer for O&M is practical. Since microcomputers now cost very little and data management system software is available, many plant operators find computers very helpful for processing O&M data in an organized fashion so that better O&M decisions can be made. At the same time, the staff is freed from handling large volumes of data manually and can therefore perform other tasks. The U.S. Environmental Protection Agency (USEPA) has issued guidelines for O&M of wastewater treatment facilities.[6] These include three sections that require a great deal of effort in data collection, calculation, manipulation, and management:

1. Records, reports, and laboratory control, including:
   a. Plant operating records
   b. Reports to regulating agencies
   c. Processing monitoring records
   d. Effluent and receiving water quality records.

2. Process control, in conjunction with:
   a. Trends or changes in influent characteristics
   b. Scheduling of routine maintenance jobs
   c. Spare parts inventory
   d. Recording of equipment maintenance and repairs.

3. Maintenance management, along with:
   a. Equipment manufacturing system identification
   b. Equipment function and location
   c. Equipment cataloging
   d. Maintenance logging.

Software packages are available that handle these tasks with great speed and accuracy. Many include special features, such as issuing work orders with priority assigned according to available manhours, preparing management reports, identifying missing data, locating where problems occur in the treatment system, and statistical analyses helpful in establishing the relationship between operational parameters with graphing capability. Some software packages have diagnostic capabilities to help treatment plant operators with operational decisions, and to perform staffing analysis, O&M cost analysis, and replacement reserve analysis. Some treatment plants expand the software capability to include word processing, bill handling, and database management, and find them very useful for these purposes.

Computerized O&M systems require considerable organization before they can work. Collecting all the data and inputting it onto the computer in a usable form requires some time and effort. However, once these tasks are done, treatment plant managers receive numerous benefits.

[6]*Federal Guidelines Operation and Maintenance of Wastewater Treatment Facilities* (U.S. Environmental Protection Agency, August 1974).

A survey[7] which obtained more than 100 responses from 35 states found the most frequent applications were:

1. Effluent quality data storage and analysis
2. Treatment process control
3. Flow monitoring
4. Flow analysis and projections
5. Maintenance data storage and analysis
6. Computer-aided design.

Appendix A lists the plants, their locations, and contacts obtained through the survey. This study also identified other wastewater treatment plants that had installed or were developing the off-line computer-aided O&M system. In addition, information was obtained through client listings and updated to December 1984 (Appendix B).

U.S. Army Experience

While the GAO has found severe noncompliance problems in civilian wastewater treatment plants, the same office also reports[8] numerous noncompliance cases in wastewater treatment plants owned by DOD. Inadequate O&M is among the many contributing factors. GAO found that 11 of 13 randomly selected DOD plants had been unable to consistently meet their National Pollutant Discharge Elimination System (NPDES) permit requirements for a number of years. These bases were formally notified of permit violations between 1977 and 1982. According to GAO's findings, continued noncompliance results from a combination of problems:

1. Lack of specific guidance on how to assure adequate operation, maintenance, and compliance
2. Deficient O&M practices, including:
   a. Inadequate staffing
   b. Lack of O&M procedures
   c. Lack of adequate laboratory support
   d. Inadequate maintenance program.

The GAO report also identified other problems with DOD wastewater treatment plants, such as design and construction.

Based on the favorable experiences of the private sector, it would be advantageous for the Army to examine the feasibility of applying a computerized system in its wastewater treatment O&M practice. On-line computerized automatic control is not yet practical for the private sector, so it is safe to assume that the same is true for the

---

[7]E. U. Graham, *WSSC/WPCF Computer Applications Survey* (Washington Suburban Sanitary Commission, March 1984).
[8]*DOD Can Make Further Progress.*

U.S. Army. While off-line computer-aided O&M has gained significant acceptance in the private sector, few Army-owned wastewater treatment plants have tested it.

This study surveyed Army use of such system applications in wastewater treatment plants. Of the 102 questionnaires sent out in October 1984, 63 Army facilities responded. Of those responding, only three had installed computer-aided systems for O&M: Fort Meade, MD; Fort Sill, OK; and Fort Rucker, AL. The Fort Rucker plant had an on-line system for flow and wastewater level control; the other two plants had off-line systems. Fort Shafter, HI, Fort Eustis, VA, Hawthorne Army Ammunition Plant, NV, and Pine Bluff Arsenal, AR, anticipated the use of computer-aided systems for wastewater treatment plant tasks ranging from training to on-line process control.

Thus, it is obvious that the use of computers for wastewater treatment plant O&M at Army facilities is just beginning. O&M deficiencies in Army treatment plants and the potential use of computer-aided systems to eliminate them make such systems worthy of consideration.

Chapters 3 through 7 will provide information useful to Army Facility Engineers in assessing the feasibility of computer-aided applications for wastewater treatment plant O&M.

3 OVERVIEW OF COMPUTER-AIDED TREATMENT PLANT OPERATION

Army Facility Engineers interested in applying off-line computer-aided treatment plant O&M systems must have answers to the following questions:

1. What does a computer-aided treatment plant operation system do?

2. What does a computer-aided treatment plant maintenance system do?

3. What are the advantages of a computerized system over a manual system?

4. What are the disadvantages of such a system?

5. Who supplies the systems and what type of service can they provide?

6. What are the costs of a computerized O&M system?

7. What are the justifications of using computer-aided systems?

8. What are the applications in various situations, including Army facilities?

To help answer these questions, this chapter provides information obtained from both the firms providing these systems and users.

Computer-Aided Treatment Plant Operation System

The main function of an off-line computer-aided system is to *manipulate data for* process control purposes. For successful operation of a wastewater treatment plant, a large volume of data must be collected. For example, the data collection requirement of a typical secondary wastewater treatment plant is an average of six pieces of data for each of about 12 functions or treatment processes. Collecting these data is very time-consuming because it involves searching, analyzing, and reporting it manually. Other processes, if required, such as chemical treatment for phosphorus removal, nitrification/denitrification, or effluent filtration, will greatly increase the data collection requirement. Similarly, the volume of data collection multiplies quickly when many of the treatment plant processes have multiple units. Other measurements, such as rainfall, temperature, and on- and off-time of a large number of treatment units, add to the total volume of data collected.

Much of the monitored data is used to calculate control parameters that treatment plant operators use to monitor plant processes. For example, the Fort Sill Treatment Plant is a 2.4-mgd* average flow trickling-filter plant with anaerobic sludge digestion, sludge-drying beds, and chemical treatment for phosphorus removal. There are 252 data points handled each day, including 30 to 40 calculated parameters. The Woonsocket Treatment Plant in Rhode Island--a 10.0-mgd average flow activated-sludge plant with no sludge treatment except vacuum filtration--collects and calculates 122 pieces of data each day. These data are recorded and filed. The data are routinely retrieved, organized, and manipulated by the computer to provide useful information in the form of reports, either periodically or on demand. Regulating agencies at the state and Federal

*Metric conversion factors: 1 mgd = 3785.4 m^3/day; 1 in. = 25.4 mm.

levels require monthly reports to monitor whether the plant meets NPDES permit requirements. Plant operators rely on daily, 7-day, and monthly reports to monitor plant performance as it relates to environmental and operational changes. Short-term to long-term changes, coupled with trend analysis using the appropriate data, will help identify operation problems. Changes in operational control and other corrective measures can then be taken.

Although data analysis can be performed manually, searching to retrieve the right data, going through the necessary calculations, and tabulating or graphing the analysis can be very time-consuming. The time requirement increases with the size of the data file and the amount of information reported to regulating agencies or treatment plant facility supervisors. An inexpensive microcomputer and software written specifically for treatment plant operation can streamline this task.

In summary, a computer-aided operation control system achieves the following:

1. Reduces the time required for recordkeeping

2. Minimizes human errors

3. Eliminates long, cumbersome data sheets

4. Eliminates tedious hand calculations

5. Permits detection of out-of-spec input data

6. Adds more calculated parameters and trend analysis than the manual version of the original report

7. Saves manpower in plant operation

8. Provides more efficient operations, possibly resulting in savings of chemicals and power

9. In some cases, provides software with the built-in capability to help the operator understand the treatment control process better, and provides some direction on how to change control steps to meet NPDES permit requirements consistently.

Computer-Aided Treatment Plant Maintenance System

Both water and wastewater treatment plants can get reliable, efficient, and cost-effective service from their equipment and personnel through an effective maintenance program. All operators can appreciate the value of reducing breakdown and repair in their plants. If service is to be continuous, either to produce drinking water or to meet wastewater effluent quality standards, there cannot be major equipment failures. However, it is unlikely that breakdown or corrective maintenance can be eliminated completely. According to American Water Works Association Manual M5, *Water Utility Management*, a reasonable objective is to spend not more than 20 percent of equipment maintenance manhours for corrective maintenance (CM). For wastewater treatment plants where equipment is used in a more hostile environment, a higher percentage can be expected. When workers spend too much time performing CM, regular maintenance work may be delayed or skipped over. Also, little attention is given to improving operational efficiency.

The following steps and considerations are basic to an organized maintenance program:

1. Use an equipment numbering system to identify equipment and locations. The plant can be divided into sections by building, location, or process, and all equipment names should be listed alphabetically in each section. A unique number should then be assigned to each piece of equipment or component.

2. From the equipment lists, draw up preventive maintenance (PM) job requirements for each piece of equipment, listing all manufacturer-recommended maintenance tasks, their frequency, and tools required.

3. Make time estimates to establish manpower requirements according to craft or trade.

4. Summarize weekly and monthly maintenance jobs for each section of the plant. Less frequently performed jobs can be included in a separate schedule that spreads the work out over a year.

5. Assign priority to the PM jobs that build in flexibility so that part of a job can be moved ahead or back to accommodate unexpected breakdown, workers' absence, etc.

6. Establish an inventory and record of parts.

7. Establish multiple lists of equipment manufacturers, parts suppliers, and special contractors who provide services to the treatment plant. Include their addresses, phone numbers, unit costs, and updated information.

8. Standardize a work order format with information on location of equipment, PM or CM history, tool and material requirements.

9. Develop a system to track the work order with information on time spent on a job, and reasons for noncompletion, so the unfinished job can be rescheduled with a higher priority.

Some maintenance programs use a card system in which one card lists the PM operations for a specific piece of equipment. The cards are filed in a box according to the next time the work listed on the card is to be done. At the beginning of every week, reference is made to the card file for work assignments for the week. The maintenance workers complete their assigned tasks, put comments on the card, and sign off on the finished job. The supervisor can then return the card to the work reminder file under the date when the work will be done next. This procedure is cumbersome and very time-consuming. The difficulty is compounded in big treatment plants where a large amount of equipment is used. However, software specifically written as a treatment plant maintenance program can store a huge volume of data and perform the maintenance program functions accurately. Tracking of equipment downtime, maintenance cost, inventory of parts, etc., is automatic and reduces human errors.

Equipped with a sound maintenance program, the plant supervisor can use the available manpower more efficiently. Rating each maintenance worker's efficiency can indicate whether the crew is operating effectively. Examining completed work orders for discrepancies could turn up problem areas. For example, differences between estimated and actual costs may indicate that estimates were inaccurate, or that workers used too much time or too much material. Records of excess equipment repairs and the

associated costs may indicate that equipment replacement is a more cost-effective alternative. Therefore, a good maintenance program helps the plant supervisor keep a close watch on the proper and most efficient use of plant equipment and personnel. Instead of reacting to crises, he/she can plan ahead. The result is improved management.

Advantages of a Computer-Aided O&M System

Computer-aided O&M systems do not replace human judgment and decisions in operating and managing the plant. At a treatment plant with sufficiently trained staff, all functions that a computer-aided O&M system can perform can be done manually. However, a computer-aided O&M system does offer several advantages:

1. An inexpensive microcomputer has sufficient memory capacity to store a huge amount of treatment plant O&M data. For example, a 10-megabyte hard disk, or about thirty 360-kbyte floppy disks, can store 3 to 4 years of O&M data for a medium-sized (10 mgd) wastewater treatment plant. On data sheets, the same amount of information would occupy several file cabinets.

2. Data retrieval, analysis, and graphing are very fast, which enables the operators to obtain information helpful in making operating and management decisions without delay.

3. More accurate and faster tracking of manhours and costs required for O&M tasks helps the supervisor in planning and budgeting.

4. Time savings in data analysis and preparation of reports allows the staff to have more time in performing other O&M tasks.

5. Since information from which better management decisions are derived can be obtained more easily, the tendency to overlook O&M problems or delay deciding to make improvements will be greatly reduced. As a result, the plant is more efficiently run, and cost savings in chemicals and power, as well as in equipment repair, are possible.

6. The user can expand use of the system to include word processing, billing, and budgeting.

Disadvantages of a Computer-Aided O&M System

The disadvantages of a computer-aided O&M system are:

1. Added cost to the treatment system. An added one-time cost of $35,000 to $50,000 could be excessive for an existing treatment plant with a limited annual budget. However, for a new treatment plant, this one-time investment is only a fraction of 1 percent up to 3 percent of the plant's first cost.

2. Initial effort and time investment in system installation, training, and startup. The amount of time and effort invested depends on the sophisticication of the software programs and on how well organized the treatment plant's manual O&M data files are. To some extent, the operators' acceptance and familiarity with microcomputer use also determine the time required.

3. Lack of acceptance of computer use. Before selecting the software program most suitable for a particular application, managers must decide exactly what they want. This is often difficult, since some managers abdicate this responsibility. Some are "afraid" of computers. Many maintenance supervisors have little or no knowledge of or exposure to computers. The potential users must be active participants in the process. Systems that are promoted by a "champion" from within will generally succeed, but even the best system will fail if no one wants it.

Whenever a new piece of equipment is added to a treatment plant, either new or as a replacement of existing equipment, time and effort must be spent to train operators and for start up. Winning operator acceptance is important. Thus, only the cost of the system should be considered a legitimate disadvantage, since any new noncomputerized equipment would also require training. The small investment of this time can produce many benefits. (Cost justification is presented on pp 24-27.)

Sources of Computer-Aided O&M Systems and Services

A computer-aided O&M system consists of a microprocessor, floppy disk and/or hard disk with disk drives for external data storage, a monitor, a keyboard, a printer, and the necessary software or programs (Figure 1).

The software that suits the user's needs is selected first, followed by selection of the proper hardware. Both can be purchased outright, but the software can be licensed out for monthly or annual fees. The user can install the program or contract the service of installation, with training and startup included as a package.

The software programs for computer-aided O&M systems are specialized data-base management systems that allow data input, organization, analysis, and retrieval according to the user's special needs. Numerous data-base management systems have been used by industries and various organizations for O&M. Recently, however, many consulting engineering firms have adapted the existing data-base management systems or developed new systems specifically for water/wastewater treatment plant O&M. Table 1 lists these firms and indicates the types of systems (i.e., O&M) and service that each provides. The types of services offered include customized service and "canned" software.

Customized service means the firm or contractor will design a program to meet a user's specific needs. The program(s) are furnished in disk form with backups. The contractor may also collect the necessary data (e.g., parts inventory, equipment information, manufacturer, location, code number, PM descriptions, etc.), input all necessary data into the program(s), start up and test the program, train the user on how to use and maintain the system, and provide continuous support. The amount of these additional services is negotiated and may include the supply of all necessary hardware. The user pays a lump sum for the hardware and the licensed software as well as a monthly or yearly fee for maintaining and updating the systems. Some firms make a lease-purchase plan available to customers. This type of service is designated as "CS" in Table 1.

Various vendors also sell software packages that are not customized. Such software may be very specific and limited in its use (e.g., diagnostic operation.) On the other hand, the program may be site nonspecific so that many plants can use the same program, but with their own modifications. These "canned" programs provide neither

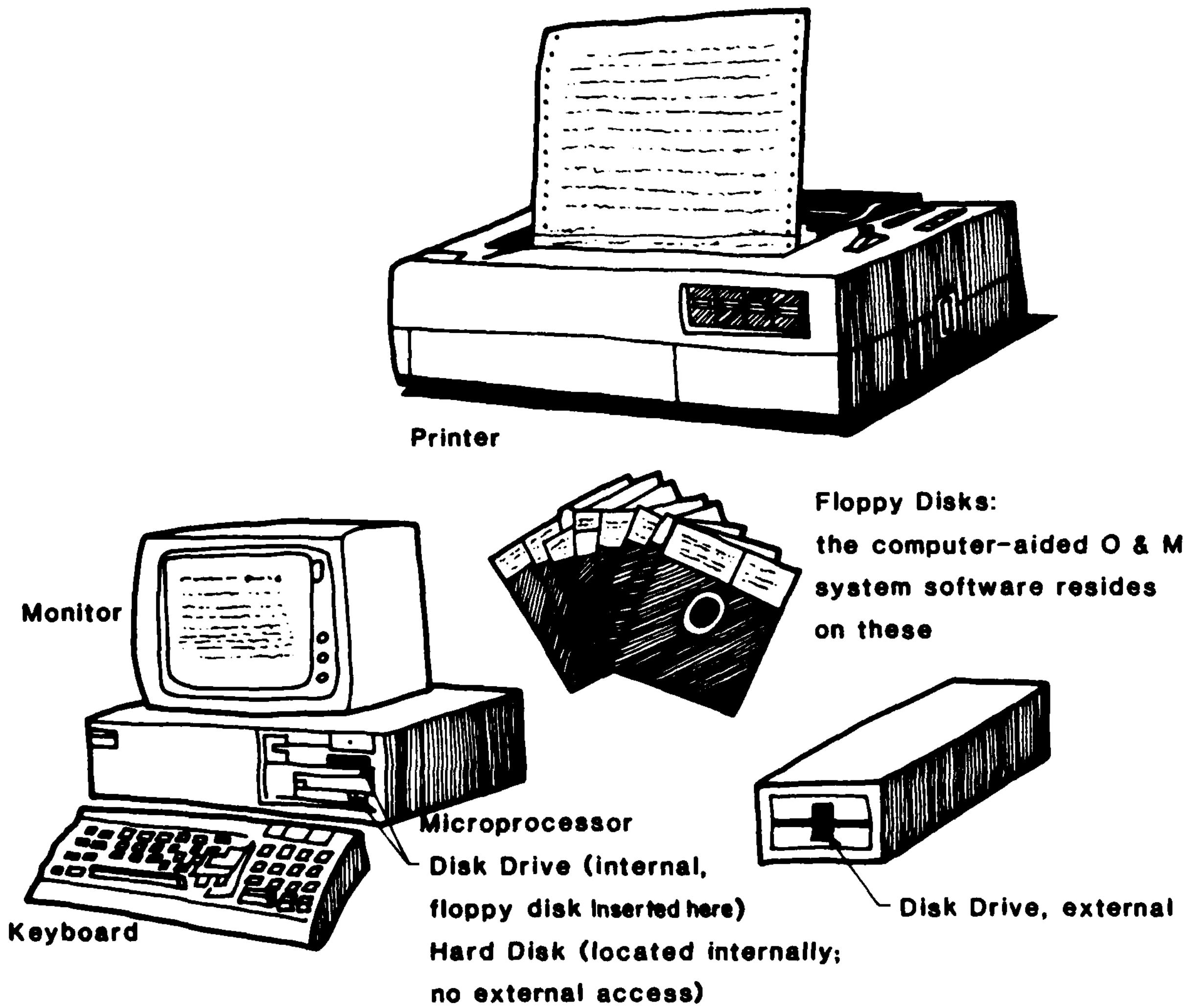


Figure 1. Hardware components.

warranties nor after-sale contract services, but are much less costly than the customized service. However, no system installation and training services are provided. This type of system is designated as "CAN" in Table 1.

Cost of Computer-Aided O&M Systems

A major concern to all treatment facilities is whether they can afford the computer-aided O&M systems. Tables 2 and 3 present the costs associated with systems available. Appendix C provides more detailed information on vendors offering hardware and software services and their price ranges.

Table 1

Firms Providing Computer-Aided O&M Systems and Services (Off-Line Systems)*

Firm	Operation System	Maintenance System	Others
Autocon Industries Inc. 2300 Berkshire Plymouth, MN 55441 (612) 553-4857	CS** CAN***	CS CAN	
Brown & Caldwell Walnut Creek, CA (415) 937-9010	CS	CS	
CH_2M Hill, Inc. 2020 S.W. 4th Ave. Portland, OR 97201 (503) 224-9190	CS	CS	
Clearwater Data System, 222 Farground Rd., N.E. Oregon (503) 364-4386			CAN (for sludge control only)
Clinton Bogert Assoc. Fort Lee, N.J. Cor Omtech Corp. 2125 Center Ave., Fort Lee NJ 07024 (800) 225-0713	CS (Same on-line control capability)	CS	
Cochrane Assoc. Inc. 236 Huntington Ave. Boston, MA 02115 (617) 247-0444	CS	CS	
Con-Tronix 3663 E. Garden Place Oak Creek, WI 53154 (414) 762-6747	CS CAN	CS CAN	CS, CAN (laboratory data management)

*This list is provided for information only and does not imply Government endorsement of these products or services.
**CS = customized software.
***CAN = "canned" software.

Table 1 (Cont'd)

Firm	Operation System	Maintenance System	Others
Datastream System EDI Technology Div. of RMT, Box 16778 Greenville, SC 29606 (803) 292-1921	CS CAN	CS CAN	
ECS Inc. Electronic and Computer Systems Div. 808 Colony Rd. Bryn Mawr, PA 19010 (215) 527-1015	CAN (activated sludge process only)		
EMA, Inc. 270 Metro Square Bldg. St. Paul, MN 55101 (612) 298-1992	CS	CS	
ES Environmental Services, Inc. Suite 213 44 Golf Club Rd. (For diagnostic only) Pleasant Hills, CA (415) 548-7970	CAN		
Services, Inc. 600 Bancroft Way Berkeley, CA 94710 (415) 548-7970	CS		
Gannett Fleming Environmental Engr. Inc. Box 1963 Harrisburg, PA 17105 (717) 763-7211	CAN (limited function)		
HDR 8404 Indian Hills Drive, Omaha, NE 68114 (402) 399-1000	CS	CS	
Jentech Rt. 1, Box 93 Gresham, WI 54128 (715) 7887-3795		CAN	

Table 1 (Cont'd)

Firm	Operation System	Maintenance System	Others
Kirkham, Michael & Assoc 91910 W. Dodge Rd. Box 14129, Omaha, NB 68114 (402) 393-5630	CS	CS	
Lotepro Corp. 1140 Ave. of the Americas, NY 10035 (212) 575-7878	CS CAN (limited to activated sludge process)	CS CAN	
Metcalf & Eddy Wakefield, MA (617) 367-4000	CS CAN	CS CAN	
Malcolm Pirnie White Plains, NY (914) 694-2100	CS CAN	CS CAN	
Patton Consultants Inc. 3699 W. Henrietta Rd. Rochester, NY 14623 (716) 334-2554	CS CAN		

Cost Justification of Using Computer-Aided Systems

Many benefits of a computer-aided O&M system cannot be quantified. Consequently, internal factors must be examined for an economic return, such as labor savings, improved maintenance, and reduction in power and material use. Also, much of the benefit is social, in terms of investment in effluent quality improvement and the associated abatement in pollution of the receiving waters.

Many areas of plant processing can yield economic return using computer-aided O&M systems. A true economic evaluation can be resolved only by plant management and supervisory personnel because they are familiar with the changes to be effected by computer implementations and with the associated influences on operational costs. In general, economic or cost justifications can be found in the following areas:

1. Savings in manpower

2. Savings in repair cost

3. Savings in chemical and power cost

4. Consistent meeting of NPDES permit requirements.

Table 2

Typical Hardware Costs for Microcomputers

	Hardware	Quoted Price 1/11/85	Range**
1.	IBM Microcomputers PCXT 256 KB (Men) 1 HD 1 0MB/1 floppy disk Monochrome display w/adapter Okidata printer (132 col., 160 char./s, model 93)	$4409*	$3063-$4808*
	PC AT 256 KB (Mem) One 1.2 MB/5-1/4-in. diskette drive Monochrome display w/adapter Okidata printer (132 col., 160 char./s, model 93)	$4166*	$1806-$3271* $4166-$7084*
2.	Apple II^{e} 64 KB (Mem) 1 HD 10MB/1 floppy disk Monochrome display Silver Reed Exp 500 (Letter Quality)	$2672	$1806-$3271*

*Includes 30 percent discount price for microprocessor.
**Depending on peripheral devices used (disk drive, cathode ray tube, printer, etc.).

Although initial implementation of a computer-aided O&M system is time-consuming, it will eventually save a lot of time in data retrieval, data tabulation, analysis, calculation, and report preparation. The Northeast Water Pollution Control Plant in Philadelphia used a computerized management information system as early as 1968. The plant is a secondary treatment plant of 175-mgd design capacity. For operation alone, about 12,000 data entries are reported during an average month. The system provides a monthly report, auxiliary reports, and eventually an annual report. It has been estimated[9] that manually preparing the rough monthly and annual reports alone, excluding typing, requires one person's time for 20 weeks. Thus, because of lack of time and personnel to do this work, the records often fall behind, and the information becomes of little use on a day-to-day basis. The computerized system provides annual estimated savings in manpower for report preparation of 1/2 man-year.

[9]C. F. Guarino, and J. V. Radziul, "Data Processing in Philadelphia," *Water Pollution Control Federation Journal*, Vol 40, No. 8 (August 1968), p 1383.

Table 3

Hardware Cost at Plant Visits

Firm & Plant	Cost Without Discount
Metcalf & Eddy, Fall River, MA	$4409
IBM PC XT 256 KB (Mem) 1 HD 10MB/1 floppy disk Monochrome display w/ adapter Okidata printer (Model 93)	
Envirotech Operating Services, Taunton, MA	$4409
IBM PC XT 256 KB (Mem) 1 HD 10MB/1 floppy disk Monochrome display w/ adapter Comparable printer	
Henningson, Durham, & Richardson	$4409
No plant visit but uses IBM PC XT	
Cochrane Associates, Woonsocket, RI	$2302
Apple II^{e} 64KB (Mem) 2 floppy disks Monochrome display Letter quality printer	

The Thorn Creek Basin Treatment Plant at Chicago Heights, IL reported[10] that the physical plant has more than doubled in size and complexity recently. Yet, because of the use of computer O&M systems, the increase in plant personnel has been only about 10 percent.

The Woonsocket Regional Wastewater Treatment Facility in Rhode Island indicates[11] that before the use of a computer-based operational management system, 25 percent of the operation supervisor's time was spent manually tracking and organizing data. The system saves nearly all that time. Much greater time savings will be realized when the plant installs a maintenance system.

[10] R. A. Davis, and J. L. Daugherty, "Computers Finally Aiding in Cost-Effective Operations, Deeds and Data," *Water Pollution Control Federation Journal* (May 1982), p 9.
[11] Personal Communication with Plant Personnel.

Insufficient staff has been identified[12] as one major cause of noncompliance in many Army-owned wastewater treatment facilities, but there is no need to add more staff with a computer-aided O&M system in place. For existing plants, the manpower savings will allow staff to devote more time to other O&M tasks that increase compliance. For new plants, O&M cost savings occur right away since a smaller staff is needed once a computer-aided O&M system is implemented.

Since the Northeast Water Pollution Control Plant in Philadelphia estimated annual savings of 1/2 man-year for operational report preparation alone, it is quite likely that annual savings of 1 man-year can be obtained easily when a computerized system is used for management reports, work order tracking, inventory equipment information, and scheduling. For a smaller treatment plant, the overall annual savings in manpower may be only 1/2 man-year. The following cost-effective analysis applies:

First cost of computer-aided O&M system	$40,000
Turnkey service including hardware, software, system installation, training, excluding maintenance data collection for smaller plants	$38,000
System life cycle	10 yr
System maintenance and enhancement	$500/yr
1/2 man-year cost savings .... (including fringe benefits and overhead)	$12,000/yr

For a small plant making an initial investment of $38,500 ($38,000 for equipment and $500 for maintenance), the net yearly savings would be $11,500 ($12,000 savings in labor minus $500 for maintenance) for the following 9 years. The rate of return in the 10-year period would be about 27 percent. For a larger plant, the initial investment would be $40,500 and savings in each of the following 9 years would be $24,500 ($25,000 labor savings minus $500 for maintenance). The rate of return would therefore be much higher. The above cost analysis does not include the cost difference between office supply cost for the computer (ribbon and paper) and the manual system (paper and typewriter support).

Savings in repair costs, as well as chemical and power costs, are very difficult to quantify. The savings could be substantial for a plant that has been poorly managed. Such a study requires collection and analysis of long periods of data collection for analysis before and after computer-aided O&M system installation. So far, no such report is available.

With the help of the computerized system, the plant is expected to meet NPDES permit requirements more consistently. This cannot be translated into cost savings except when a few treatment plants are fined by regulating agencies for permit violations.

---

[12] *DOD Can Make Further Progress.*

In summary, cost savings can be quantified only in manpower savings. This section has presented the amount that a large or small treatment plant can save by installing a computer-aided O&M system. There are other gains, such as meeting NPDES permit requirements more consistently, increasing the recreational value of the receiving water, and intangible benefits such as better plant management.

Army Applicability

The two major contributing factors to DOD wastewater treatment noncompliance are insufficient staff and lack of staff training.[13] These problem areas can be significantly minimized by using the computer-aided O&M systems.

The technical and cost justifications of using a computer-aided system to overcome the problem of understaffing were presented earlier in this report. The Army can also take full advantage of the turnkey service offered by many vendors. In customizing the software programs, the vendor will discuss with the facility owner, manager, and staff the specific O&M task needs. The vendor has the expertise to improve O&M procedures essential for treatment performance compliance, including data collection, calculation, organization, and analysis. The manager and staff can contribute the facility's hands-on experience to assist with program design. The custom-design process of the software program gives the entire staff an opportunity to understand and to re-evaluate necessary O&M techniques.

Some Army wastewater treatment plants may have well-qualified and properly trained personnel, but are still understaffed. These plants could purchase and install the computer-aided O&M system to improve their O&M efficiency. Timely and correct O&M decisions cannot be obtained at an understaffed plant without using a computer to process the data quickly and accurately.

With the hardware installed, the facility owner can expand its use by purchasing other "canned" programs for specific purposes or through a program enhancement contract with the vendor. Chapter 4 describes general and specific software programs.

---

[13] *DOD Can Make Further Progress.*

4 COMPUTER-AIDED OPERATION MANAGEMENT SYSTEM

A typical water or wastewater treatment plant operation using an off-line computer-aided operation management system consists of a hardware-and-software system that provides speedy and automatic data processing. Information on these hardware and software systems was collected from vendors and from owners/operators of treatment facilities where such systems are being used. Site visits were also conducted to investigate the operators' experience and their evaluation of the computer-aided operation management systems.

Most systems investigated were applicable to primary, secondary, and tertiary wastewater treatment plants that include both liquid-train and solid-train processes. Although these systems were used primarily to manage wastewater treatment plants, the same data management systems can be applied to a water treatment facility.

This chapter presents an overview of the processes involved in working with a computer-aided operation management system. It is based on a detailed analysis of typical operation management systems used in treatment plants. In particular, the systems listed in Table 4 were reviewed for this analysis. The table also presents the accompanying hardware-software units used for the systems.

Table 4

Computer-Aided Operation Management Systems Reviewed for Analysis of Basic Functions

Vendor	Hardware	Software
Envirotech Operating Services (EOS)	IBM PC/XT 10-Mb hard disk Epson Printer	EOS operating system
Metcalf & Eddy	IBM PC/XT 10-Mb hard disk Okidata Printer	Records Operational Management System (RODA)
Cochrane Assoc. Inc.	Apple II 64-K memory Epson Printer	TREDAT system
Henningson, Durham & Richardson Engrs. (HDR)	7080-based microcomputer terminal - Cyber 170 Mainfame	Laboratory Process Control Data Management System

Functions of an Off-Line Computer-Aided Operation Management System

The major objective of a computer-aided operation management system is to store and process the operational data and to perform computational tasks to aid in decision making for daily plant operations. Figure 2 shows the basic functions of a computer-aided operation management system. The particulars of each function and the format in which the results are presented depend on the hardware capacity and software capabilities.

Although the basic functions of the four operation management systems investigated were similar, the formats for performing various tasks were distinct for each operating system. Taking into account the various features of each operation management system, the following sections summarize the basic functions and various computational tasks performed by a computer-aided operation management system.

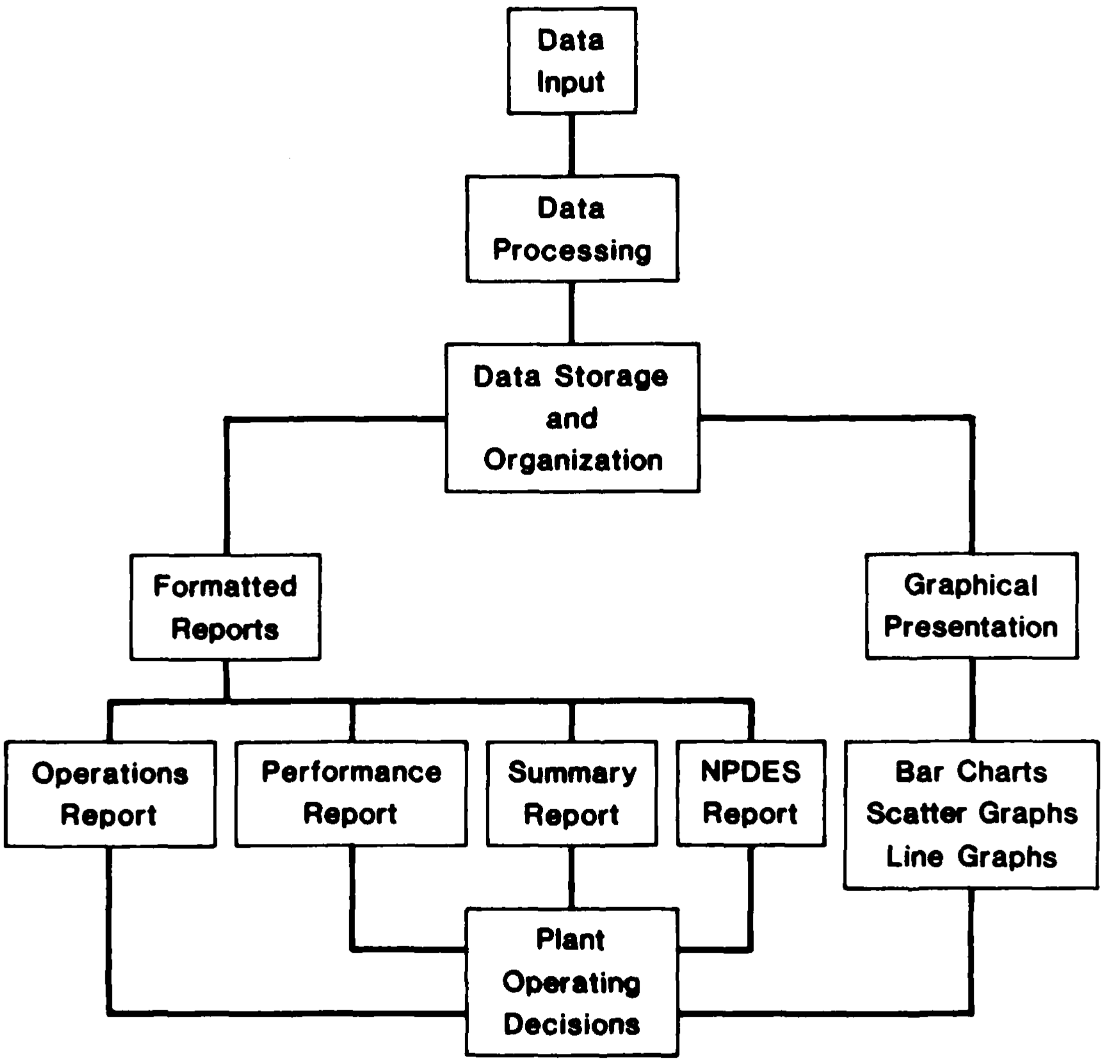


Figure 2. Basic functions of a computer-aided operation management system.

Data Entry System

Data required for computations to evaluate plant performance are entered into the computer system interactively. The format for data input varies with the operating system. In general, however, the data entry program permits the operator to enter, edit, and review information regarding process control and other operational parameters. All data entered can be stored permanently on disks and used for data analysis and production of performance reports.

The data entry systems of all four operational management systems reviewed (Table 4) can maintain all daily data entered and all calculated parameters. The data can be retrieved quickly and hardcopy printout obtained. The systems can organize all records from past to present concerning operation and are flexible enough to allow changes in key parameter inputs. Metcalf & Eddy and EOS operational systems have a special feature which identifies the units currently on-line and thus eliminates unnecessary data entries.

Production of Formatted Reports

Data entered into the computer operating system are analyzed, computed, and organized to summarize plant performance in a desired format. The data analysis and presentation of results are designed to provide a perspective of overall plant performance as well as individual treatment unit operations for any specific period. The formatted reports provide an efficient way to view plant reliability and to control all aspects of process management.

The computer-generated reports are typically classified as:

1. Operations reports--daily, weekly, or monthly

2. Performance reports
   a. Unit processes
   b. Overall plant

3. Summary reports

4. NPDES state and local compliance reports.

These reports often list the operational data of a treatment unit or process for a specified period. Results of simple statistical analysis, such as minimum, maximum, and average values of the parameters, are also commonly included. Figure 3 shows a typical monthly report for a digester operation.

In general, the operation management systems evaluated can produce reports of daily operations which summarize key parameters. The Metcalf & Eddy and the EOS systems can generate weekly and monthly operations reports for a specific treatment unit. The EOS system has a feature that can generate flash reports summarizing averages and trends for key parameters. This report also has a warning system to indicate abnormal operating conditions. All four systems can directly print out NPDES permit compliance information in the state or city formats. Parameters exceeding the specified NPDES limits can be highlighted in all but the HDR system.

Fort Sill WWTP
Monthly Report
DATA FOR APRIL 15 - 30 1985

Thu MAY 9, 1985

Digester Operations

DATE	Digester #1 Temp (F)	pH	TS (%)	VS (%)	Digester #2 Temp (F)	pH	TS (%)	VS (%)
15	79	7.0	3.8	51.5	74	7.3	1.3	54.5
16								
17								
18								
19								
20								
21								
22	83	7.1	4.7	47.0	70	7.2	0.2	66.7
23								
24								
25								
26								
27								
28								
29	82	6.9	3.3	45.0	75	7.3	0.2	50.0
30								
TOTAL	244	21.0	11.8	143.5	219	21.8	1.7	171.2
MINIMUM	79	6.9	3.3	45.0	70	7.2	0.2	50.0
MAXIMUM	83	7.1	4.7	51.5	75	7.3	1.3	66.7
AVERAGE	81	7.0	3.9	47.8	73	7.3	0.6	57.1

Figure 3. Digester operation monthly report.

Graphic Data Presentation

Many wastewater treatment plant supervisors and managers prefer to see operational data summarized graphically. Visual data presentation helps detect trends in plant performance. The most common form of graphic data presentation is the plot of temporal variation of a specific parameter. The plots are generally presented as bar charts, scatter graphs, or line graphs. Plotting several parameters on the same graph for a specific unit operation is also commonly used to visualize trends.

Graphic presentation of a specific operational parameter's effect on plant performance can be used to make operating decisions. Such graphs are useful for evaluating the correlation between parameter variation and treatment plant performance when establishing operating characteristics.

The Metcalf & Eddy system generates graphs for a specific process, plotting four parameters and up to 365 days of data on one graph. Figure 4 shows a typical temporal plot of three parameters for 2 months of data. Plots of the data can be formatted in either scatter graphs or line graphs. This system can also generate graphs that plot parameter variation against unit operation performance.

The EOS system uses a graphics subsystem which can present data in bar charts or scatter plots but not in line graphs. It cannot present the parameter effects on plant performance, but it can present up to four graphs on the same page. The graphic data presentation of Cochrane Associates, Inc., TREDAT system can plot multiple-day moving averages for key parameters.

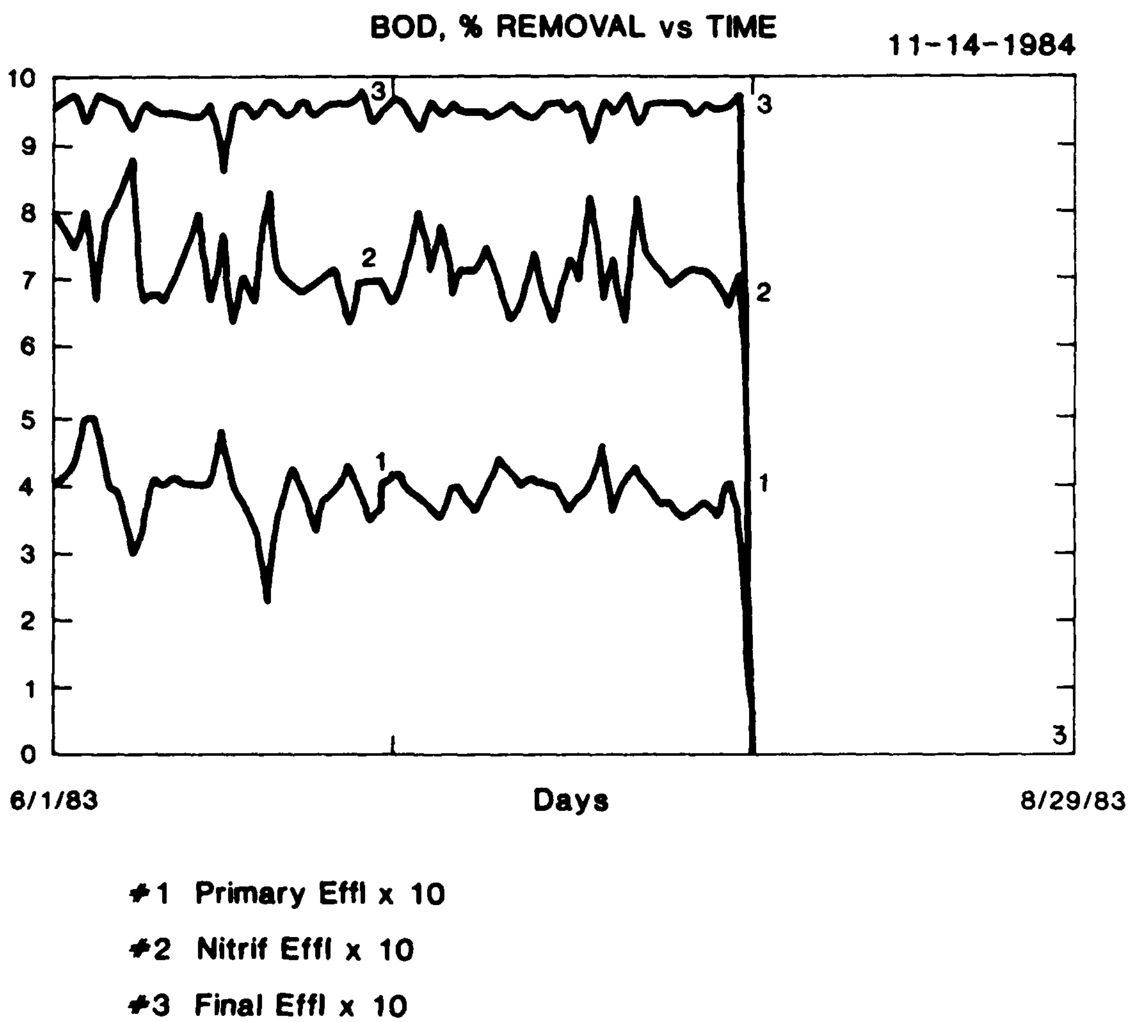


Figure 4. Typical graphical representation of treatment plant operations data (Metcalf & Eddy Operational Management System).

Operational Trend Analysis and Problem Diagnosis

A desirable function of a computer-aided operation management system is operational trend analysis which identifies problems so they can be corrected before they become critical. Formatted reports and graphic presentations generated by computers help the operator/manager locate the problem areas quickly and take positive actions to correct the situation. However, diagnosis of a problem may not be apparent from the reports and graphs alone. Mathematical modeling of the treatment unit processes can be used to simulate, and thus predict, plant performance under various steady-state conditions.

The problem diagnosis and plant performance simulation abilities of the operation management systems reviewed (Table 4) were somewhat limited. The forecast of plant performance was generally based on observations of daily trends and comparison of observed and expected values of the key parameters. General warnings to indicate abnormal average parameter values are stated in the reports.

Besides the systems listed in Table 4, another system, known as ES Environmental Service Diagnostic Operational Programs, was reviewed. This system has software, compatible with Apple II computers, specifically designed to help engineers sort out the possible operational problems associated with plant noncompliance with NPDES permits.

The ES Environmental Services Diagnostic Operational Programs could independently model the various wastewater treatment unit processes which include:

1. Primary treatment
2. Conventional activated sludge with primary clarification
3. Conventional activated sludge without primary clarification
4. Single-stage trickling filter
5. Two-stage trickling filter
6. Extended activated sludge with primary clarification
7. Extended activated sludge without primary clarification
8. Oxidation ditch with primary clarification
9. Oxidation ditch without primary clarification
10. Contact stabilization with primary clarification
11. Contact stabilization without primary clarification
12. Rotating biological contactors
13. Activated bio-filter with primary clarification
14. Activated bio-filter without primary clarification.

Plant performance under steady-state conditions could be simulated by selecting the desired plant configuration and the influent wastewater characteristics.

This program can also be used to develop treatment plant configurations and strategies to meet the NPDES permit regulations. However, it should be noted that the program provides predicted performance rather than actual performance results. It is useful for periodic plant evaluation rather than daily use. The U.S. Army Facilities Engineering Support Agency, Fort Belvoir, VA, has used this program to evaluate five Army facilities:

1. Fort Eustis, VA--trickling filter

2. Fort Lewis, WA--trickling filter

3. Fort Benning, GA--trickling filter

4. Youngson, Korea--rotating biological contactors

5. Camp Humphreys, Korea--rotating biological contactors.

The USEPA has encouraged the use of this program by state regulating agencies to evaluate plant performance.

Applications of Computer-Aided Operation Control Systems

It is important to recognize the limitations of the computer-aided operational control systems. The system will not replace the sound judgment and decisions of the plant manager and operation personnel, who should be knowledgeable about treatment plant operation. The off-line computer system does not give instructions on how to operate the plant or how to improve its treatment performance. Vendors often claim that the system's advantage is improving plant performance and avoiding effluent violations; however, it does not do this automatically. More often, the human element is the overriding factor. When a properly designed off-line computer-aided system is used, the speedy data organization and analysis give the operating personnel early opportunities to review the current status of how the plant is functioning, the direction in which the plant is going, and the magnitude of influent variations (quantity and quality) as well as operational control changes and the treatment responses. These will lead to early and timely decisions by the staff so that necessary corrections can be made. The system makes it possible to anticipate problems and to initiate corrective action before the problems occur. Therefore, the treatment plant can perform efficiently and can meet the designed effluent quality standards more consistently.

Another important factor in applying the computer-aided operational system is acceptance by the plant personnel who will use it. Data collection and data analysis are essential for a successful treatment plant O&M program, whether it is manual or computer-aided. The user must commit fully to such an endeavor and be consistent. Because of its organized nature, the user will find the time savings and the ease of use provided by the fully implemented system very rewarding. In fact, he/she can expand the system to include budgeting and word processing, so that the investment can be returned in a short period of time. With full commitment, benefits can be maximized.

5 COMPUTER-AIDED MAINTENANCE MANAGEMENT SYSTEMS

Apart from making proper operation management decisions to produce effluent quality complying with NPDES permit regulations, appropriate maintenance management is required to ensure continued and fail-safe treatment plant performance. Computer-aided maintenance systems permit the operator/manager to keep track of the scheduled maintenance for various treatment plant components, in a minimum amount of time; this increases productivity by reducing equipment breakdown time.

The principles of maintenance management systems are similar to those of operation management systems. The data relating to maintenance requirements are entered into a computer using specific software for data input. The data are then organized and processed to produce various reports for use in management decisions.

The basic functions of a computerized maintenance management system were delineated by analyzing of some of the available major systems being used in wastewater treatment plants. The systems investigated included Metcalf & Eddy, Inc., Computerized Parts and Equipment Management (COPE); Envirotech Operating Service, Maintenance Management System (EOS - MMS); Henningson Durham & Richardson, Maintenance Management System (HDR - MMS); and Jentech, Inc., Maintenance Management System. These systems are compatible with specific hardware systems prescribed by the vendor. The following sections briefly survey the basic functions of a maintenance management system.

Functions of a Computer-Aided Maintenance Management System

A computerized maintenance management system is typically divided into four subsystems:

1. Preventive maintenance management (PM)

2. Corrective maintenance management (CM)

3. Equipment inventory management

4. Spare parts inventory management.

These subsystems can independently or interactively maintain, organize, and process data, and can print reports in various formats. However, in most management systems reviewed, some of the functions were common for different subsystems. Following is an overview of the subsystems' basic functions.

Preventive Maintenance Management

Figure 5 is a schematic of the functions of a PM management subsystem. PM is probably the major type of maintenance function encountered in a wastewater treatment plant. The PM tasks are generally listed by components, such as motors or pumps. The listing can be cross-referenced with other descriptors such as equipment ID and manufacturer's serial number. The equipment ID also describes the location and functions of the equipment. The PM listing provides details such as task description, estimated time for the task, and required tools.

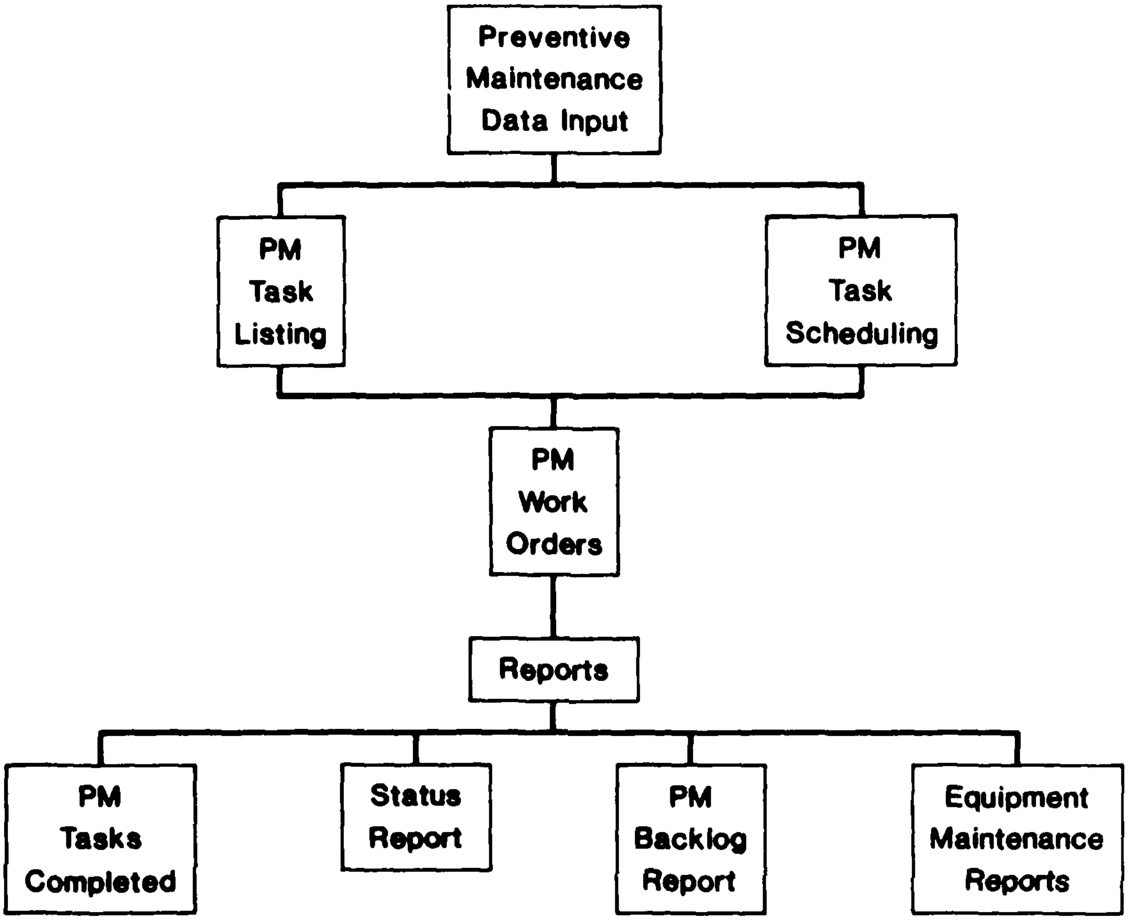


Figure 5. Basic functions of computer-aided preventive maintenance management subsystem.

The tasks listed are scheduled based on manhours available for each trade. Some systems, such as Metcalf & Eddy's COPE program, can prioritize the tasks based on frequency of the PM, elapsed time from last PM job, etc. After scheduling, a work order (Figure 6) for the PM task can be printed out from the computer. When the tasks are completed, the system is updated and rescheduled for the next PM task. A report on the status of the PM workload schedule may be used for work-tracking and for making specific assignments to an individual worker. Figure 7 shows a typical PM workload scheduling. Depending on the system, the workload schedule can also list the tasks in sequential route throughout the plant, which helps eliminate needless traveling between jobs. A detailed analysis of PM tasks completed can be performed to evaluate the manpower needs and productivity of the maintenance crew.

Corrective Maintenance Management

Figure 8 is a schematic description of CM functions. Computerized CM management is generally used to generate work orders detailing pertinent information such as description of the problem, equipment location, and tasks to be performed. It also maintains records of all CM tasks performed for any specific equipment.

```
05-23-1985                          Maintenance Procedure ID: GENERATOR-1

      COPE  --  Computerized Parts and Equipment Management
                FT. GEORGE G.  MEADE AWT FACILITY

          OPERATIONS (OP) PREVENTIVE MAINTENANCE WORK ORDER

       UNIT: EQU-0008                        SEQUENCE #:     5
  COMPONENT: GENERATOR                       JOB NUMBER:
             FE-1220
   LOCATION: EASTSIDE                   LOCATION NUMBER:  2000
   SHOP DWG:                                 PART INDEX: EASTSIDE
     MANUAL: VOL.14                           NAMEPLATE: GENERATR
=================================================================
    PM TASK:  RUN GENERATOR    UNDER LOAD      TIME:    45 mins
DESCRIPTION:  1) CHECK OIL LEVELS, FUEL LEVEL, AND AIR CLEANER
              2) MAKE SURE AUTO SWITCHES ARE IN AUTO AT UNIT
              3) AT SUBSTATION, SWITCH TO TRANSFER OF POWER
              4) ELECTRICAL LOAD OF PLANT SHOULD BE TRANSFERRED
                 TO GENERATOR (EXPECT A SEVERAL SECOND LAG TIME
                 FOR GENERATOR ENGINE TO COME UP TO SPEED)
              5) RUN GENERATOR UNDER LOAD FOR ABOUT 20 MINUTES
              6) CHECK WITH OPERATIONS STAFF TO INSURE ALL
                 EQUIPMENT TOOK TRANSFER OF POWER FROM EMERGENCY
                 BACK TO NORMAL.
        SMP:                        CURRENT RUNTIME:      101 hours
    LAST PM:  12/04/1984                  FREQUENCY:    30 days
                    101 hours                            5 hours
-----------------------------------------------------------------
    MATERIALS:  1) BE SURE TO FOLLOW           STARTUP PROCEDURE
                   FROM SUBSTATION.         2) HAVE AN OPERATOR
                   AVAILABLE TO CHECK          OUT EQUIPMENT DURING
                   TRANSFER OF POWER.       3) MAKE NOTE OF OIL
                   LEVELS, WATER TEMP,         FUEL, AND INSPECTION

SPECIAL TOOLS:  WIPE DOWN RAGS              LOG BOOK FOR GENERATOR
                PEN OR PENCIL
=================================================================
      DATA ENTRY: COMP ID-TASK    ACTUAL TIME       DATE
                  FE-1220-  1     _______ min     __________

JOB COMPLETED BY: ________________________________________
```

MATERIALS USED

ITEM	PART NUMBER	QUAN	UNIT $	TOTAL $

REMARKS:

Figure 6. Preventive maintenance work order format—COPE Maintenance Management System.

05-23-1985 COPE -- Computerized Parts and Equipment Management Page 1
2:12:20 pm

FT. GEORGE G. MEADE AWT FACILITY

Preventive Maintenance Scheduling Summary

TRADE	DESCRIPTION	AVAILABLE HOURS	REQUIRED HOURS	SCHEDULED HOURS	SCHEDULED NUMBER TASKS	BACKLOGGED HOURS	BACKLOGGED NUMBER TASKS	HOURS FREE
OP	OPERATIONS	1	9.5	0.8	1	8.8	4	0.3
T0	THOMAS	1	5.5	1.0	2	4.5	23	0.0
T1	SHEDLOCK	1	4.9	1.0	6	3.9	18	0.0
T2	MAINTENANCE	12	55.5	12.0	24	43.5	92	0.0
T3	BOYKINS	12	5.4	5.4	25	0.0	0	6.6
T4	POND	1	10.7	1.0	2	9.7	20	0.0
T5	FLETCHER	1	6.7	1.0	1	5.7	28	0.0
T6	BAHR	1	2.9	0.8	5	2.1	9	0.2
T8	MARINE	1	4.4	1.0	2	3.4	17	0.0
T9	SZUBA	1	3.6	1.0	3	2.6	10	0.0
**	TOTALS	35	123.2	20.0	82	95.2	272	7.0

Figure 7. Format for allocation of available manhours for preventive maintenance for any trade—COPE Maintenance Management System.

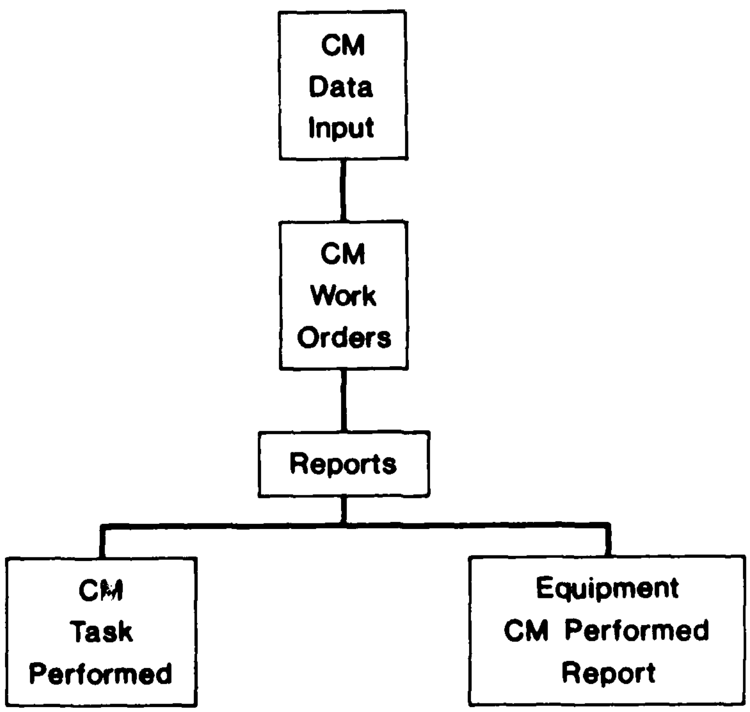


Figure 8. Basic functions of computer-aided CM management.

Typical reports generated by CM management subsystems include a status report of CM tasks, CM work history of any specific equipment or for any specific period, and equipment repair cost. These reports can be used to detect patterns of problems and to make decisions to minimize problem occurrences.

Equipment Inventory Management

The objective of the equipment inventory management subsystem is to manage records of various equipment and components throughout the treatment plant. Figure 9 shows the functions of this subsystem.

The equipment information entered into the computer generally includes name-plate data, manufacturer's manual reference, spare parts information, and special tool requirements. Details of PM and CM works performed on the equipment are also recorded from the PM and CM subsystems. Figure 10 shows a typical printout of equipment information. Data from this system can be retrieved in various report forms for use in management decisions.

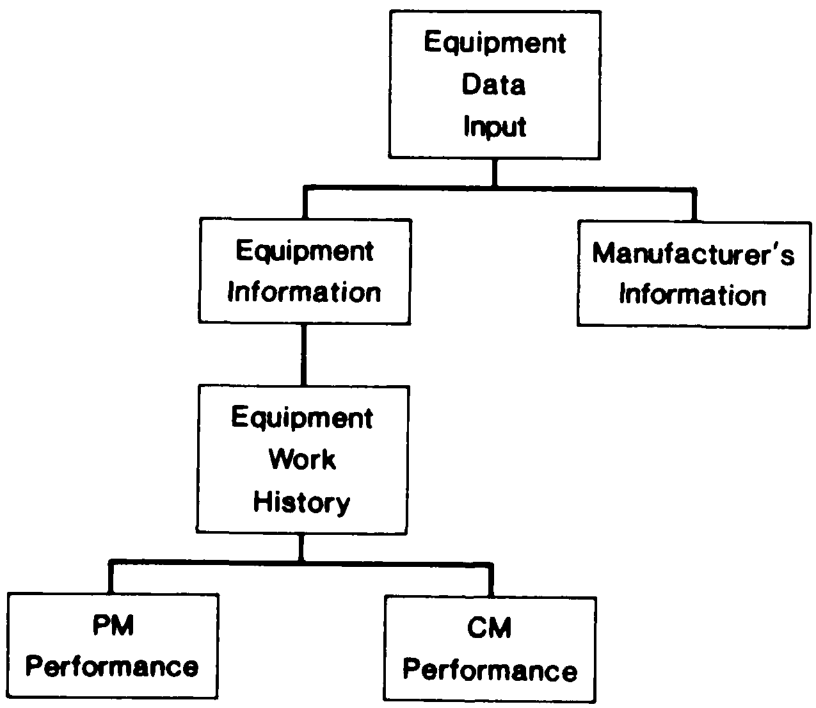


Figure 9. **Basic functions of computer-aided equipment inventory management subsystem.**

```
EOS CAMEO - MMS                                        FAIRFIELD-SUISUN WWTP
EQUIPMENT INFORMATION                                  MON  12/17/84
==============================================================================
Eq #  00111  Eq Name  GRIT TRUCK
------------------------------------------------------------------------------
Location    UV    ! Reference #  4230    ! Eq Type          Eq Group
------------------------------------------------------------------------------
Manufacturer/Rep  INTERNATIONAL                         Phone  (    )000-000
------------------------------------------------------------------------------
Serial Number                  ! Model   LOADSTAR      ! Size   1300
==============================================================================
                               !              WORK SUMMARY
                               !
                               !  Purchased  00/00/00   Cost $            0 00
                               !
                               !  YTD WO             9  Life WO             27
                               !  YTD CM Hr         20  Life CM Hr          54
                               !  YTD Mat $      75.00  Life Mat $     1660.97

==============================================================================

Eq #  01010  Eq Name  #1 INLET PUMP
------------------------------------------------------------------------------
Location    A     ! Reference #  A-1010  ! Eq Type          Eq Group
------------------------------------------------------------------------------
Manufacturer/Rep  WORTHINGTON PUMP                      Phone  (    )000-000
------------------------------------------------------------------------------
Serial Number   75-2001178     ! Model                 ! Size   6600 GPM
==============================================================================
                               !              WORK SUMMARY
                               !
                               !  Purchased  01/00/75   Cost $            0.00
                               !
                               !  YTD WO             0  Life WO              6
                               !  YTD CM Hr          0  Life CM Hr          53
                               !  YTD Mat $       0.00  Life Mat $     4667.04

==============================================================================

Eq #  16120  Eq Name  WASTE WATER PUMP #2
------------------------------------------------------------------------------
Location    LSP   ! Reference #          ! Eq Type          Eq Group
------------------------------------------------------------------------------
Manufacturer/Rep                                        Phone  (    )000-000
------------------------------------------------------------------------------
Serial Number                  ! Model                 ! Size
==============================================================================
                               !              WORK SUMMARY
                               !
                               !  Purchased  00/00/00   Cost $            0.00
                               !
                               !  YTD WO             8  Life WO              8
                               !  YTD CM Hr         14  Life CM Hr          14
                               !  YTD Mat $     758.54  Life Mat $      758.54

==============================================================================
```

Figure 10. Format for reporting equipment information, listing, work summary, and history—EOS Maintenance Management System.

Spare Parts Inventory Management

Rigorous management of spare parts inventory is required to avoid delays in performing PM and CM tasks. The functions of spare parts inventory management for all the equipment on hand includes the vendors' addresses and telephone numbers and the status of parts on order. Figure 11 is a schematic of the spare parts inventory management subsystem's functions.

The major types of reports it generates include parts listings, vendor listings, and status of parts on order. The parts could be listed by cross-referencing to the stock number, storage location, equipment group, or vendor. The data from this subsystem can be retrieved and formatted into reports useful for keeping track of inventory.

Application of Computer-Aided Maintenance Management Programs

Computer-aided maintenance management programs can be very useful in streamlining a treatment plant operation. However, most systems require considerable interaction with the computer to derive maximum benefits. The functions of the management programs discussed here are general and are based on reviews of available systems. Specific systems must be consulted to determine the exact functions the program can offer.

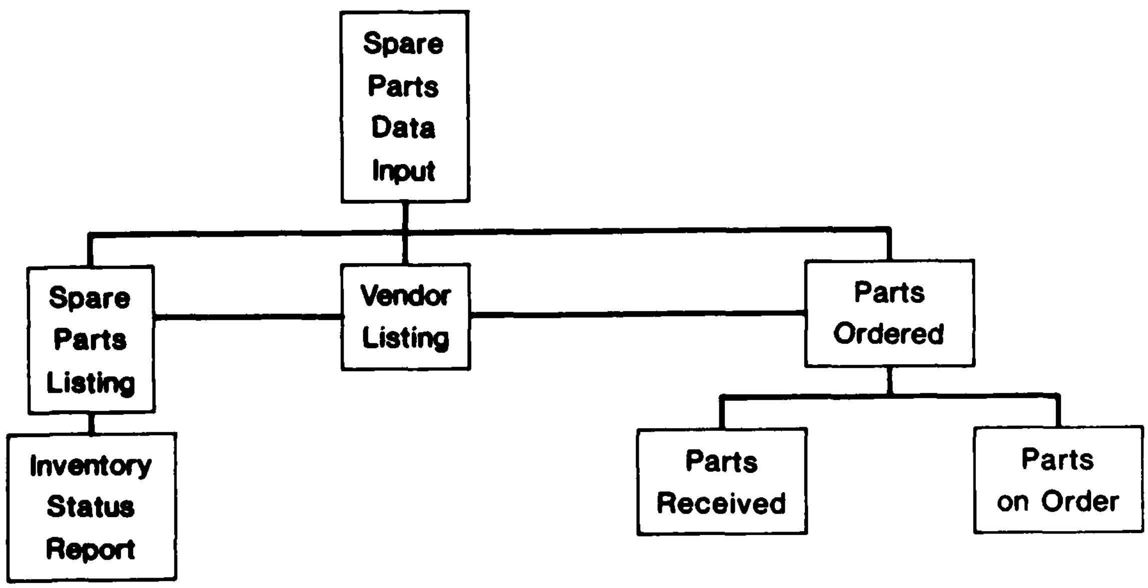


Figure 11. **Basic function of computer-aided spare parts inventory management subsystem.**

6 FIELD DEMONSTRATIONS AT ARMY INSTALLATIONS

Recognizing the potential benefits of using a computer-aided O&M system in water and wastewater treatment plants (WWTP), USA-CERL conducted a Facilities Technology Applications Test (FTAT) to demonstrate the applicability of the technology at an Army base. Through an arrangement with the U.S. Army Training and Doctrine Command, Fort Sill, OK, was chosen as a demonstration site.

The Fort Sill WWTP is a very small facility with an average daily dry weather flow of 2.6 mgd, and a 4.2-mgd design flow. It is an older plant with 193 pieces of equipment that are maintained regularly by plant operators. The treatment plant is very well run, with plant performance consistently good and effluent quality superior. Fort Sill's computerized O&M system was developed by Envirotech Operating Services (EOS).

A second site chosen was the Fort Meade Advanced Wastewater Treatment Facility (AWWTF), designed by Metcalf & Eddy, Inc. (M&E), and built and put on line in May 1982. Although the plant has only a 4.5-mgd design flow capacity, the NPDES permit demands sophistication in treatment and an abundance of equipment (500 pieces). The concept of using a computer-aided O&M system as an efficient management tool was appealing. Using a system made available from M&E seemed logical, even though similar software was commercially available elsewhere.

This chapter describes the experiences of Forts Meade and Sill and the reactions of plant personnel to the computerized systems, examines system cost-effectiveness, and investigates plant performance improvements.

Fort Sill Computer-Aided O&M System Experience

EOS provided the following services to the Fort Sill WWTP for $33,218:

1. Review, organize, and format data for system input

2. Create and format O&M reports as requested by Fort Sill personnel

3. Conduct on-site user orientation and hands-on training in system use

4. Provide complete software package user's manual

5. Provide continuous support for 1 year following system installation with year-end review and evaluation of the system.

The software ran on an IBM/XT personal computer with 128KB additional memory, an IBM monochrome monitor with printer interface, and an Epson printer. The hardware components were off-the-shelf items. The total effort for collecting equipment inventory information was estimated to be 25 man-days. However, because much of the equipment was older, locating service manuals and manufacturer plates was often difficult or impossible. After the equipment inventory information was gathered, EOS began system installation.

By October 1984, the system was installed and running, data were being entered, and plant personnel were being trained. Table 5 shows the progress of system

installation. While actual system installation takes relatively little time, gathering equipment information, report formatting, and later modifications are time-consuming. EOS was given 30 days to deliver the system, including manuals and user training, and another 12 months for system installation and implementation.

Table 5

Progress of Software System Installation and Implementation at Fort Sill WWTP

September 1984	Operation system installation
October	2-day training session for three WWTP personnel on the use of the operation system.
	Implementation of the data entry program element of the operation system.
	Installation of standard package for the maintenance system.
	2-day training session for three WWTP personnel on concept of computer-aided management technique.
November/December	Modification of program elements of both the operation and maintenance systems.
January 1985	During the week of January 5th, training of three WWTP personnel in the use of the maintenance system. Specific implementation and training included work order cycle, organizing equipment listings, stock listings, master request forms, and equipment information forms.
February	Design and completion of the DA report generator coding system.
March	Installation of the control files for the DA report generator (DA reports 4247, 4178, and 4141).
	Training of two WWTP personnel in use of the report generator.
	General system support, including several adjustments to data entry process, adding effluent parameters to the database, minor changes to existing process reports.
	Minor adjustments to the maintenance system.
April/May	General system support and adjustments to both the operation and maintenance systems.

The following operation system program elements were implemented:

1. Data Input: Data entry and calculated parameters (daily, weekly, and biweekly).

2. Unit Process Report: Available for every treatment unit at the WWTP.

3. Tabular Reports: Called "monthly reports," but generated biweekly for the superintendent and upper management personnel; included reports on weather/influent data, raw sludge, digested sludge, BOD, TSS, and digester operations. Figure 12 shows a report from the system.

Fort Sill WWTP
Monthly Report
Data for April 15-30 1985

Page 7 of 9
Thu May 9, 1985

Effluent Concentrations

DATE	pH	Free Chlorine (mg/1)	Eff. Temp (F)	Total Phosphate (mg/1)	D.O. (mg/1)	% Sat	Fecal Colif (#100)	Turb. (ntu)
15	6.60	0.50	71	0.70				4.5
16	6.60	0.50	70	1.00				5.0
17	6.60	0.60	70	0.65				4.5
18	6.60	0.60	70	0.70	4.90	54	0	4.3
19	6.60	0.50	72	0.70				4.0
20	6.60			1.15				
21	6.60			0.50				
22	6.70	0.30	68	2.30				6.5
23	6.70	0.75	69	0.70			0	3.0
24	6.60	0.75	69	0.51				3.0
25	6.70	0.75	69	0.45	4.90	52	0	3.2
26	6.70	0.75	69	0.47				3.7
27	6.60			0.70				3.7
28	6.60			0.32				
29	6.70	0.75	70	0.52				3.7
30	6.60	0.50	71	0.52			0	3.0
TOTAL	106.10	7.15	837	11.89	9.80	106	0	48.4
MININUM	6.60	0.30	68	0.32	4.90	52	0	3.0
MAXIMUM	6.70	0.75	72	2.30	4.90	54	0	6.5
AVERAGE	6.63	0.60	70	0.74	4.90	53	1	4.0

Note: Fecal coliform average calculated as a geometric mean.

Figure 12. Tabular report form (EOS System) at Fort Sill.

4. DA Reports: Posting of DA report forms 4247, 4178, and 4141 onto computer sheets on which the monthly monitoring reports were generated by the computer (it was hoped that in the future the reports could be printed directly on computer paper to save more time).

5. Data Summary Reports: Available but very seldom generated because at a small plant like Fort Sill, tabular reports could serve as summary reports.

6. Data Plotting: Used occasionally, with future use expected to increase with the amount of data stored.

One program element--the generation of flash reports--was not executed at all, since the tabular reports served this function well for a small plant like Fort Sill. NPDES permit reports and weekly operation reports were generated manually.

Although the EOS standard maintenance system package included many elements, only a few were implemented at the Fort Sill WWTP:

1. Open Work Order: Generated when work was needed on a piece of equipment.

2. Closed Work Order Listing: (see Figure 13).

3. Equipment Listing: An important system element that requires much initial work to gather the proper information for input to the computer (see Figure 14).

4. Equipment Work Summary: Another program element that allows the supervisor to see the condition of any piece of equipment.

5. Part Listing: A complete list of WWTP parts, their locations, and quantity on hand.

EOS CAMEO -- MMS FT SILL WWTP
CLOSED WORK ORDER LISTING MON 12/32/84
Mechnical Craft
Interval: 12/01/84 to 12/31/84

Page No. 00001 Mechanical Closed WOs by WO Number (12/01/84-12/31/84)

WO#	COMP DATE	AGE (D)	LOC	EQUIPMENT & NO NAME	DESCRIPTION	CSE CDE	TIME	TOTMAT COST
** TOTAL **								
		0					0.0	0.00

Figure 13. Closed work order listing at Fort Sill (EOS System).

E O S C A M E O - MMS
EQUIPMENT LISTING

FORT SILL WWTP
MON 12/31/84

PAGE NO. 00001
12/31/84

Equip No	Group	Name	Loca tion	Manufacturer	Phone
					/ -
					/ -
ALMM	ALP	ALUM PUMP MIDDLE MOTOR GOES W/ALPM	T5931	BALDOR IND.	/ -
ALMM	ALP	ALUM PUMP NORTH MOTOR	T5931	GENERAL ELECTRIC	/ -
ALMN					/ -
ALMS	ALP	ALUM PUMP SOUTH MOTOR GOES W/ALPS	T5931	GENERAL ELECTRIC	/ -
ALPM	ALP	MIDDLE ALUM FEED PUMP	T5931	PENNWALT WALLACE/TIERNAN	/ -
ALPN	ALP	NORTH ALUM FEED PUMP	T5931	PENNWALT WALLACE TIERNAN	/ -
ALPS	ALP	SOUTH ALUM FEED PUMP	T5931	PENNWALT WALLACE/TIERNAN	/ -
BARE	BAR	EAST BARMINUTOR UNIT P - TYPE CCCC2, 24"		CHIC. PUMP @ CONTRACT DEP	/ -
BARW	BAR	WEST BARMINUTOR UNIT P - TYPE CCCC2, 24"		CHICAGO PUMP @ CNTRCT DEP	/ -
BFCI		BACK WASH FLOW CONTROL VALVE	T5931		
BWV1		BACKWASH VALVE #1	T5931	CHICAGO FLUID POWER	/ -
BWV2		BACKWASH VALVE #2 5/8 STROKE)	T5931	CHICAGO FLUID POWER	/ -
BWV3		BACKWASH VALVE #3 (5/8 STROKE)	T5931	CHICAGO FLUID POWER	/ -
BWV4		BACKWASH VALVE #4 (5/8 STROKE)	T5931	CHICAGO FLUID POWER	/ -
CEC1	CEP	V-800 CHLORINATOR ELECTRIC CONTROL	T5931	WALLACE & TIERNAN	/ -
CEC2	CEP	V-800 CHLORINATOR ELECTRIC CONTROL	T5931	WALLACE & TIERNAN	/ -
CHL1	CHL	CHLORINATOR	SWP1	WALLACE AND TIERNAN	/ -
CHL2	CHL	CHLORINATOR	SWP2	WALLACE AND TIERNAN	/ -
CHL3	CHL	CHLORINATOR	SWP3	WALLACE AND TIERNAN	/ -
CHL4	CHL	CHLORINATOR	SWP4	WALLACE AND TIERNAN	/ -
CHL5	CHL	CHLORINATOR	SWP5	WALLACE AND TIERNAN	/ -
CHL6	CHL	CHLORINATOR	SWP6	WALLACE AND TIERNAN	/ -
CHD1		50-125 CHLORINE DETECTOR	T5931	WALLACE & TIERNAN	/ -
CMP1	CMP	CHEMICAL BUILDING COMPRESSOR - WITH TANK CMT1	T5931	KELLOG AMERICAN	/ -
CMP2	CMP	CHEMICAL BUILDING COMPRESSOR	T5931	KELLOG AMERICAN	/ -
CMPD	DCP	PRIMARY DIGESTER	H5923	CARTER	/ -

Figure 14. Equipment listing from EOS system at Fort Sill.

The following features were available, but were not implemented at the Fort Sill WWTP: preventive maintenance schedule report, PM task listing, PM workload schedule, open work order summary, parts on order, vendor listing, equipment information, maintenance history report, and backlog open work order.

So far, the Fort Sill experience indicates that only a portion of the standard EOS O&M System package was implemented. The following discussion offers several reasons for this.

Size of the WWTP

The Fort Sill WWTP is a very small facility, with the plant operators regularly doing preventive maintenance jobs such as greasing, checking belts, bearings, etc. There are few work orders, and parts inventory is always well under control. There are no electricians or mechanics by trade at the WWTP. When a corrective maintenance or repair job is beyond the capability of the operators, an electrician, mechanic, or plumber is sent by the Facility Engineer's Office. In addition, equipment parts are ordered by personnel from the Directorate of Engineering and Housing. For a bigger facility with a lot of equipment, a larger maintenance crew with different crafts or trades, and a huge inventory of parts, the use of program elements such as PM scheduling, backlog WO, parts order, and maintenance flash reports, would be justified.

Existing Plant Management

The Fort Sill WWTP is a very well run plant. It has a very large equalization capacity which dampens the fluctuation of quantity and quality of incoming sewage loads. Plant performance is consistently good, providing superior effluent quality. Laboratory personnel keep a close watch on the treatment units and take frequent sample analyses. The plant superintendent examines the records and analyses daily. He works closely with the treatment plant staff, which consists of only two other operators on other shifts. The director of public works at Fort Sill examines the biweekly reports (tabular reports) to oversee the plant operation. The close supervision of the plant operation and the confidence of the staff eliminate the need for multilevel reports that the EOS O&M system offers larger treatment plants.

Insufficient Database

For better use of the maintenance system, a sufficient database is needed, including equipment work summary and history, work orders, and backlogs, allowing the supervisor to make timely management decisions. Similarly, a sufficient database is required to demonstrate trends in seasonal change of chemical use, utility use, and effluent quality. At this time, about 6 months of data has been collected. The Fort Sill WWTP personnel and the Environmental Officer feel that more extensive use of the EOS system can be expected after more data has accumulated.

Fort Sill WWTP personnel estimate that about 50 percent of the available program elements are now used. Generally, 15 minutes are spent each weekday for data entry into the computer daily data files. Preparation of the biweekly tabular reports requires 1-1/2 hours with the computer system. Preparation of the 10 DA reports requires more time. The technique of manually aligning the computer printer head with the DA forms pasted onto the computer sheets has not yet been perfected. Presently, about 5 manhours are required to prepare the 10 DA reports from the computer system each month. Half of this time could be saved if the manual alignment difficulty could be

overcome. More time could be saved if the Fort Sill Facility Engineer's Office could submit the DA monitor reports printed on computer papers instead of on the standard DA forms.

At this time, the regulating agencies (the regional Environmental Protection Agency and the Oklahoma and Texas Departments of Water Resources) require that the log book and calculations by the laboratory staff be kept manually. Consequently, data handling and entry are done manually each day and the data are saved for computer entry once a week. Unfortunately, this duplication of effort cannot be avoided. However, generating the reports by computer does save time. The nine-page biweekly tabulated report prepared by the computer system could save 2 manhours every 2 weeks. With the present difficulty of printer-head alignment, the generation of the 10 DA monitoring reports saves no time. Nonetheless, manhour savings could be realized in preparing the monthly NPDES permit reports and in generating special on-demand reports, since data retrieval using the computer system is almost effortless. Since there is no need for a large number of reports in the Fort Sill WWTP operation and maintenance, the savings of manhours is currently meager. At most, 1 manday per month is saved.

Discussion with Fort Sill personnel indicates that both the director of public works and the WWTP superintendent are in favor of the computer-aided O&M system. Both see potential for more extensive use of the system when, in the near future, there is sufficient accumulation in the O&M database. The ability to request updated or historical data quickly, to see the cost and manhour distribution in all O&M activities, and to be able to justify a budget request based on cost data, work orders, and backlogs make management personnel feel they could use these tools more efficiently. The two WWTP operators who have received training in using the maintenance software system are equally happy to use the system whenever they can. The situation is slightly different with the laboratory staff who have used the operation software system. The regular duties of collecting samples, sample analysis, data logging and calculation, and preparing reports, fully occupy their time. The new requirement of data entry and report generation using the computer system, but without eliminating much of the manual process of data handling, actually creates extra work for them. A parttime laboratory technician has recently left, and the position has not yet been filled, so the remaining personnel have even more work. However, if this position is filled, there will be better use of the computer-aided O&M system.

All installed program elements are consistently implemented. The chief of the laboratory staff considers the program beneficial to treatment plant operation for three main reasons: (1) it provides correlation patterns of chemical feed to contaminant removal, (2) it generates useful reports, and (3) it helps to keep the operating personnel familiar with the process.

The training provided by EOS in system use seems adequate. The plant superintendent can use both the operation and maintenance systems. The two laboratory personnel can work independently with the operation system, while two operator/maintenance crew members can work independently with the maintenance system. Typical of a new system and infrequent use, the users occasionally show lack of familiarity with the process. With the help of the manuals, the difficulty is always overcome. Some reminders from the other staff are always helpful. The software did not include report formatting, so the staff cannot add, delete, and change report parameters. Although EOS provides such services with the current contract, future support services must be secured.

The interaction between EOS representatives and the Fort Sill WWTP personnel has been productive. Some staff feel that EOS could have done more of the program modification before coming to Fort Sill so that more of the time could have been used for training. Some also feel that the data entry procedure is not as streamlined as it could be. There are always minor changes that need to be made from time to time. So far, EOS has been very quick to provide help by sending instructions over the phone or by sending floppy disks with the necessary changes.

Fort Sill Conclusions

Overall, Fort Sill personnel approved of the system, and more extensive use of the program elements is anticipated. The project has 3-1/2 more months before completion, and changes and enhancements to the software are still taking place every month. On one hand, this indicates that WWTP personnel are working patiently with EOS to streamline the software program. On the other hand, progress is being made slowly because plant personnel are still logging and calculating data manually, thereby duplicating some efforts. Discussion of lessons learned from this FTAT project and suggestions as to how application to other Army facilities can be improved are provided on p 59.

Fort Meade Computer-Aided O&M System Experience

For the Fort Meade demonstration, it was decided to negotiate a turnkey contract with M&E, who would supply all the necessary hardware and software, and provide the installation, implementation, and training for the O&M system. The contract also provided for program enhancements and updates in the future at little or no cost, as well as user manuals. The operation system software, called RODA, was leased for $25,000, including $12,400 for labor (installation, implementation, training, and program maintenance) and overhead. Leasing the maintenance system software, called COPE, cost $30,000, including $21,000 for labor and overhead.

The hardware cost about $8000 and included an IBM/XT personal computer with a 10-megabyte additional memory, a color monitor, and an Okidata printer. (It should be noted that the prices given here no longer reflect current prices because the personal computer market changes constantly. Since the current price trend is downward, the prices given here are higher than would currently be found in the market.)

Equipment inventory information was to be collected by the Fort Meade AWWTF personnel and recorded on forms provided by M&E. The staff spent about 160 manhours to gather the information. There are about 500 pieces of equipment at the plant, compared to only 193 pieces at the Fort Sill WWTP. However, the plant was new when the equipment inventory was taken, which made information collection much easier.

M&E representatives worked closely with the AWWTF staff to customize the program elements. Different program elements were phased in slowly between late 1982 and the end of 1983. Formal training was given to AWWTF personnel for 2- to 3-day sessions, with one for the RODA program and another for COPE. After another 1-day self-learning session, the staff could operate both systems. Routine use of both RODA and COPE began in early 1984. A few brief periods of interruption occurred due to personnel turnover and program difficulties, which included program debugging, program updates/enhancements, and malfunction of the computer clock.

The following program elements of the RODA operating system were implemented at the Fort Meade AWWTF:

1. Data Entry: Data entry and calculated parameters daily.

2. Daily Operating Reports: Routinely recall operational data from all treatment units to generate one report for each unit in operation; however, this was not generated since the 7-day and monthly operating reports were considered more useful.

3. Seven-Day and Monthly Operating Reports: Routinely generated for various aspects of plant operation. Figure 15 shows a monthly vacuum filtration report from the Fort Meade facility.

4. Performance Summary Reports: Includes the NPDES report. The regional USEPA office accepts the computer printout as such without using the official EPA Form 3320-1.

VACUUM FILTRATION REPORT
Ft. Meade AWT Facilities
From Apr 1, 1985 to Apr 30, 1985
Date Requested: 05-22-1985 Page 2 of 3

		TS%	LOADING DRY LBS PER HOUR				LBS REM	LBS RECY	REMOVAL
Date	Day	CAKE	SLUDGE	LIME	FeCL3	TOTAL	SOLIDS	SOLIDS	EFFEC. %
1	Mon	21.0	16092			16092			
2	Tue	23.0	9650			9650			
3	Wed	21.0	6159			6159			
4	Thu	22.0	6357			6357			
5	Fri	21.0	9536			9536			
6	Sat								
7	Sun								
8	Mon	21.0	6159			6159			
9	Tue	23.0	10558			10558			
10	Wed	23.0	12669			12669			
11	Thu	23.0	12669			12669			
12	Fri	22.0	15062			15062			
13	Sat	22.0	9536			9536			
14	Sun								
15	Mon								
16	Tue	23.0	20156			20156			
17	Wed	23.0	20764			20764			
18	Thu	24.0	23199			23199			
19	Fri								
20	Sat								
21	Sun								
22	Mon	22.0	10331			10331			
23	Tue	23.5	13052			13052	1284	11768	9.8
24	Wed	23.0	15121			15121	1332	13789	8.8
25	Thu	20.0	20383			20383	1558	13825	7.6
26	Fri	22.0	692			692	14	678	2.1
27	Sat								
28	Sun								
29	Mon	23.0	10331			10331	947	9383	9.2
30	Tue	23.0	20383			20383	1886	18497	9.3

Figure 15. Monthly vaccum filtration report from M&E system at Fort Meade.

5. Chemical and Utility Report: Generated monthly for use of electricity, fuel oil, Cl_2, SO_2, water, polymer, lime, and $FeCl_3$.

6. Special Monitoring Reports: Replaces DA forms 4247, 4178, and 4141 with computer printouts (Figure 16) for monitoring the operating performance throughout the plant; this eliminates all the cumbersome work required of the Fort Sill WWTP in printing DA forms.

The M&E COPE maintenance system standard package includes many program elements, of which the following were implemented at Fort Meade:

1. File Maintenance: Routine backup of data on one floppy disk.

2. Preventive Maintenance Schedule for Operation: Task listing with task description, PM last performed, priority, etc.

3. PM Tasks Performed: List for PM performed for a specific date or period of time.

4. PM Scheduling Summary: Listing for the supervisor of the hours available, required, scheduled, backlogged, and free for individual staff, for any time period.

5. PM Scheduled for Each Staff Member.

6. PM Scheduled for Maintenance: Listing with task description, PM last performed, priority, etc. (Figure 17).

7. PM Backlog for Operating: Task listing with task description, last performed, priority, etc.

8. PM Backlog for Each Staff Member.

9. PM Backlog for Maintenance: Task listing with task description, last performed, priority, etc.

10. Operation PM Work Order.

11. PM Work Order for Each Staff Member.

12. Equipment Run Time Entry.

13. Corrective Maintenance Data Entry.

14. Equipment Reference Library Report.

15. Equipment History Report: Listing of maintenance work performed for each piece of equipment with repair type, trade, downtime, etc.

16. Outstanding Corrective Maintenance Work Order Report.

17. Data File Usage Statistics: For database integrity verification, data entry, change of passwords, etc.

18. History Data Archive: Data backup and transfer for a specific period of time.

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Apr 1, 1985 to Apr 30, 1985
Date Requested: 05-23-1985

Date	Day	Weather: Rain in	Weather: Temp of	Sewage Flow, MGD: min	Sewage Flow, MGD: total	Sewage Flow, MGD: max
1	Mon			1.40	2.44	3.00
2	Tue			1.40	2.19	3.00
3	Wed			1.30	2.04	3.00
4	Thu			1.10	2.04	2.20
5	Fri			1.00	1.74	2.40
6	Sat			.40	1.74	2.20
7	Sun			1.10	1.68	2.40
8	Mon			1.00	1.98	3.00
9	Tue			1.00	2.22	3.20
10	Wed			1.20	1.19	2.80
11	Thu			.90	1.33	3.00
12	Fri			.40	1.53	3.00
13	Sat			1.20	1.84	2.50
14	Sun			1.10	1.89	2.60
15	Mon			2.00	2.21	3.00
16	Tue			1.10	2.21	3.00
17	Wed			1.10	2.21	3.20
18	Thu			.80	3.03	3.20
19	Fri			2.20	3.18	3.20
20	Sat				2.62	
21	Sun			.80	3.06	2.40
22	Mon			.40	3.60	3.80
23	Tue			.80	3.23	3.50
24	Wed			1.20	3.29	3.90
25	Thu			.80	1.31	2.80
26	Fri			2.40	3.31	3.00
27	Sat				2.89	
28	Sun				2.42	
29	Mon			.90	3.61	3.40
30	Tue				3.49	
Average				1.16	2.87	2.96
Median				1.10	2.21	3.00
Minimum				.80	1.19	2.20
Maximum				2.40	3.61	3.90
Total		***		****	71.22	***

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Apr 1, 1985 to Apr 30, 1985
Date Requested: 05-23-1985

RAW INFLUENT

Date	Day	Temp °C mg/l	BUD mg/l	TDS mg/l	TSS mg/l	VSS ml/l	SETT cu. y	Grit
1	Mon	15.0					10.5	
2	Tue	15.0					11.5	
3	Wed	15.0					11.0	
4	Thu	16.0	94		100	84	8.0	
5	Fri	15.0					6.0	
6	Sat	15.0						
7	Sun	16.0					2.0	
8	Mon	17.0					10.0	
9	Tue	16.0	83		57	48	13.0	
10	Wed	16.0					13.0	
11	Thu	16.0			55	48		
12	Fri	16.0						
13	Sat	16.0						
14	Sun	16.0					6.0	
15	Mon	18.0					14.0	
16	Tue	18.0	83		98	90	14.0	
17	Wed	18.0					10.0	
18	Thu	18.0	60		67	46	10.0	
19	Fri	18.0					11.5	
20	Sat	18.0					5.0	
21	Sun	18.0					2.0	
22	Mon	20.0					8.0	
23	Tue	20.0	114		157	128	10.5	
24	Wed	20.0					10.5	
25	Thu	20.0	118		153	129	14.0	
26	Fri	20.0					8.5	
27	Sat	20.0					14.0	
28	Sun	20.0					8.0	
29	Mon	20.0						
30	Tue	20.0			170	152	10.0	
Average		17.5	92		107	91	9.6	
Median		18.0	94		100	90	10.0	
Minimum		15.0	60		55	46	2.0	
Maximum		20.0	118		170	152	14.0	
Total		****	***	***	***	***	****	

Figure 16. Format for reporting NPDES permit requirements adapted at Fort Meade, MD, treatment plant.

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Apr 1, 1985 to Apr 30, 1985
Date Requested: 05-23-1985

RAW INFLUENT

Date	Day	TP mg/l	OP mg/l	NH3 mg/l	TKN mg/l	PH	ALK mg/l
1	Mon					6.8	211
2	Tue					6.8	113
3	Wed					6.7	113
4	Thu					6.8	154
5	Fri					6.7	116
6	Sat					6.7	117
7	Sun					6.8	144
8	Mon					7.1	200
9	Tue	5.5		160.0		6.9	97
10	Wed			17.4		7.3	205
11	Thu	5.6		17.0		7.1	
12	Fri					6.8	122
13	Sat	6.4				7.0	112
14	Sun					6.7	130
15	Mon	7.0				6.7	199
16	Tue	6.8		17.0		6.7	199
17	Wed			15.4		6.6	125
18	Thu	4.6		18.0		6.9	130
19	Fri					6.8	98
20	Sat					6.7	
21	Sun					6.5	
22	Mon			18.0		6.7	135
23	Tue	6.2		16.5		6.8	127
24	Wed			18.2		7.2	145
25	Thu	6.8		12.7		7.0	135
26	Fri					6.8	120
27	Sat					6.9	142
28	Sun					6.6	120
29	Mon			12.0		6.8	
30	Tue					6.7	200
Average		6.1		29.3		6.8	143
Median		6.4		17.0		6.8	130
Minimum		4.6		12.0		6.5	97
Maximum		7.0		160.0		7.3	211

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Apr 1, 1985 to Apr 30, 1985
Date Requested: 05-23-1985

PRIMARY EFFLUENT

Date	Day	BOD mg/'	TSS mg/l	TP mg/l	OP mg/l	NH3 mg/l	TKN mg/l	PH	Turb ntu	ALK mg/l
1	Mon							6.9	10.0	263
2	Tue							9.2	8.9	189
3	:Ved							7.6	7.5	198
4	Thu	28	68					3.4	11.6	232
5	Fri							8.2	12.0	189
6	Sat							8.3	12.0	199
7	Sun							8.1	11.0	304
8	Mon							9.0	14.0	340
9	Tue	71	173	2.2		15.5		9.1	13.5	200
10	Wed					16.0		9.1	10.0	268
11	Thu		270	1.0		15.0		8.4	9.4	
12	Fri							9.4		194
13	Sat			1.7				8.8	13.4	178
14	Sun							8.2	15.0	195
15	Mon			2.4				8.3	15.0	222
16	Tue	73	132	2.5		15.8		8.8	15.0	222
17	Wed					15.8		9.1	12.5	194
18	Thu	69	186	2.1		16.5		8.5	15.0	165
19	Fri							8.8	23.0	179
20	Sat							8.3	23.0	
21	Sun							9.0	11.0	
22	Mon					16.5		9.1	10.0	188
23	Tue	73	43	1.5		15.0		9.2	13.0	186
24	Wed					16.5		9.3	13.0	196
25	Thu	63	25	.6		16.1		9.8	8.5	182
26	Fri							9.3	15.0	188
27	Sat							8.5	13.0	196
28	Sun							8.5	11.0	175
29	Mon					13.1		8.7	14.0	
30	Tue		21					8.6	12.9	309
Average		63	115	1.8		15.6		8.5	12.9	213
Median		71	132	2.1		15.8		8.8	12.9	195
Minimum		28	21	.6		13.1		3.4	7.5	165
Maximum		73	210	2.5		16.5		9.8	23.0	340

Figure 16 (Cont'd)

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Apr 1,1985 to Apr 30, 1985
Date Requested: 05-23-1985

		NITRIFIED EFFLUENT						FILTER EFFLUENT			
Date	Day	BOD mg/l	TSS mg/l	TP mg/l	NH3 mg/l	PH	ALK mg/l	Turb ntu	TSS mg/l	TP mg/l	Turb ntu
1	Mon					6.9	168	.5			.4
2	Tue					6.9	98	.5			.3
3	Wed					7.6	96	3.4			.8
4	Thu	7.6	37.0	1.9		9.1	247	13.0			5.4
5	Fri					1.4	189	6.3			2.3
6	Sat					8.3	105	6.5			2.3
7	Sun					7.8	350	5.7			2.8
8	Mon					8.0	290	5.2			5.0
9	Tue	12.4	10.8	1.1	10.1	7.7	210	4.5			3.4
10	Wed				10.1	7.5	218	3.5			2.8
11	Thu		5.4	.8	9.9	7.5		2.5			1.8
12	Fri						570				
13	Sat			.9		10.3	98	13.5			6.0
14	Sun					8.8	282	16.0			2.8
15	Mon			1.6			355	12.0			5.5
16	Tue		20.0	1.5	9.0	8.3	355	12.0			5.5
17	Wed				13.0	7.9	220	12.5			3.2
18	Thu		24.5	1.1	15.5	8.7	200	10.0			4.0
19	Fri					8.8	220	6.5			3.0
20	Sat					7.0		3.8			1.8
21	Sun					6.8		1.8			.9
22	Mon				15.5	7.2	1.37	1.4			.6
23	Tue	2.8	1.2	.4	.1	7.4	140	1.5	.5		.7
24	Wed				.1	7.1	116	1.2			.6
25	Thu	3.0	1.6	.3	.1	7.0	101	1.0	3.0		1.0
26	Fri					7.1	112	1.6			1.0
27	Sat					6.9	133	1.0			.8
28	Sun					6.9	125	1.0			.8
29	Mon					7.1		1.2			.7
30	Tue		2.4			7.1	175	.9	3.2		.6
Average		6.5	12.9	1.1	8.2	7.5	207	5.2	2.2		2.3
Median		7.6	10.8	1.1	10.1	7.5	189	2.4	3.0		1.8
Minimum		2.8	1.2	.3	.1	1.4	96	.5	.5		.3
Maximum		12.4	37.0	1.9	15.5	10.3	570	16.0	3.2		6.0

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Apr 1, 1985 to Apr 30, 1985
Date Requested: 05-23-1985

		CL2		SO2	Final Effluent						
		Dos	Res	Dos	CL2 Res mg/l			Turb	PH		
Date	Day	#/day	mg/l	#/day	1 Rd	2 Rd	3 Rd	ntu	1 Rd	2 Rd	3 Rd
1	Mon	65.0	2.4	40.0	0.00	0.00	0.00	.3	6.7	6.9	6.9
2	Tue	68.0	2.0	40.0	0.00	0.00	0.00	.4	6.7	6.8	6.7
3	Wed	83.0	2.8	40.0	0.00	0.00	0.00	.7	6.7	7.8	7.6
4	Thu	95.0	1.5	40.0	0.00	0.00	0.00	6.4	9.6	8.8	8.4
5	Fri	68.0	1.8	40.0	0.00	0.00	0.00	2.3	7.5	7.4	7.4
6	Sat	97.0	1.8	40.0	0.00	0.00	0.00	2.3	7.9	7.9	7.9
7	Sun	100.0	1.8	40.0	0.00	0.00	0.00	2.8	7.3	7.4	7.3
8	Mon	110.0	2.2	49.0	0.00	0.00	0.00	5.0	7.5	7.2	7.7
9	Tue	105.0	2.2	40.0	0.00	0.00	0.00	3.5	7.9	7.0	7.2
10	Wed	107.0	1.3	40.0	0.00	0.00	0.00	2.7	7.3	7.7	7.3
11	Thu	110.0	1.5	40.0	0.00	0.00	0.00	1.5	7.2	7.8	7.7
12	Fri	115.0	1.8	40.0	0.00	0.00	0.00	7.3		9.0	10.8
13	Sat	110.0	1.4	40.0	0.00	0.00	0.00	5.8	9.2	9.0	9.3
14	Sun	100.0	1.5	40.0	0.00	0.00	0.00	2.8	9.3	8.9	8.9
15	Mon	115.0	1.9	40.0	0.00	0.00	0.00	5.5	8.6	7.8	7.7
16	Tue	115.0	1.9	40.0	0.00	0.00	0.00	5.5	812	7.8	2.7
17	Wed	110.0	2.2	40.0	0.00	0.00	0.00	4.0	7.4	7.4	7.6
18	Thu	135.0	1.8	52.0	0.00	0.00	0.00	3.5	7.8	7.3	7.4
19	Fri	125.00	3.0	48.0	0.00	0.00	0.00	2.7	7.0	7.0	7.0
20	Sat	100.0	1.8	40.0	0.00	0.00	0.00	1.0	7.0	6.8	6.6
21	Sun	100.0	1.8	40.0	0.00	0.00	0.00	.6	6.8	6.6	6.7
22	Mon	198.0	.2	50.0	0.00	0.00	0.00	.6	6.9	6.8	6.7
23	Tue	205.0	.0	50.0	0.00	0.00	0.00	.9	6.8	6.8	6.7
24	Wed	200.0	.2	30.0	0.00	0.00	0.00	1.0	6.8	6.8	6.8
25	Thu	300.0	.2	30.0	0.00	0.00	0.00	.9	7.1	7.1	6.8
26	Fri	167.0	.1	30.0	0.00	0.00	0.00	.7	6.8	6.9	6.9
27	Sat	135.0	.7	40.0	0.00	0.00	0.00	.8	6.7	6.6	6.9
28	Sun	100.0	1.6	40.0	0.00	0.00	0.00	.8	6.7	6.9	6.8
29	Mon	125.0	2.8	46.0	0.00	0.00	0.00	.7	6.8	6.7	6.6
30	Tue	107.0	1.5	40.0	0.00	0.00	0.00	.9	6.7	6.7	6.8
Average		122.3	1.6	40.8	0.00	0.00	0.00	2.3	7.4	7.4	7.3
Median			1.8		0.00	0.00	0.00	1.5	7.2	7.2	7.2
Minimum		65.0	.0	30.0	0.00	0.00	0.00	.3	6.7	6.6	2.7
Maximum		300.0	3.0	52.0	0.00	0.00	0.00	6.4	9.6	8.6	10.8
Total		3670.0		1225.0							

Figure 16 (Cont'd)

MONTHLY OPERATING REPORT
Ft. Meade AWT Facilities
From: Date Apr 1,1985 to Apr 30, 1985
Date Requested: 05-23-1985

FINAL EFFLUENT | COLIFORM

Date	Day	Diss. Oxy mg/l 1 Rd	2 Rd	3 Rd	NH3 mg/l	TP mg/l	BOD mg/l	TSS mg/l	TOT # /	FECAL 100 ml
1	Mon	8.2	8.7	8.1						1
2	Tue	8.4	8.7	8.2						
3	Wed	8.3	8.5	7.6						
4	Thu	8.0	8.8	8.6	26.3		33.0	5.5		190
5	Fri	8.5	8.2	8.3						
6	Sat	8.2	8.4	8.4						
7	Sun	6.4	6.4	7.8						
8	Mon	8.0	5.9	5.5						
9	Tue	8.6	7.6	7.8	10.1	1.20	15.0	8.2		
10	Wed	8.2	11.2	8.6	9.9					
11	Thu	8.4	9.0	8.6	7.0	.76		3.0		
12	Fri	8.6	9.0	8.8						
13	Sat	8.4	8.1	8.2		1.50				
14	Sun	8.0	8.2	9.0						
15	Mon	8.6	6.5	7.2		1.20				
16	Tue	8.6	6.5	7.2	7.0	.69	20.0	4.6		1
17	Wed	7.3	8.7	8.4	13.0					7
18	Thu	8.4	8.3	9.9	14.0	.38	16.1	5.6		
19	Fri	8.3	8.5	8.3						
20	Sat	8.4	8.7	8.5						
21	Sun	8.0	7.8	7.4						
22	Mon	7.6	7.8	8.4	14.0					400
23	Tue	8.6	7.9	8.3	.3	.38	2.2	.5		
24	Wed	8.0	8.8	8.6	.1					800
25	Thu	8.0	8.7	8.4	.1	.30	3.0	2.8		
26	Fri	8.0	8.1	7.8						
27	Sat	8.4	8.3	8.6						
28	Sun	8.0	6.9	6.8						
29	Mon	8.4	8.5	8.3	.1					1
30	Tue	8.4	8.6	8.3				3.2		
Average		8.2	8.2	8.1	8.5	.80	14.9	4.2		200
Median		8.3	8.4	8.3	9.9	.76	16.1	4.6		7
Minimum		6.4	5.9	5.5	.1	.20	2.2	.5		1
Maximum		8.6	11.2	9.9	26.3	1.50	33.0	8.2		800

MONTHLY OPERATING REPORT
FT. MEADE AWT FACILITIES
From: Apr 1,1985 to Apr 30, 1985
Date Requested: 05-23-1985

NITRIFICATION BASIN #1

Date	Day	MLSS mg/l	MLVSS mg/l	SSVS mg/l	SSV30 mg/l	SfG #	Temp °C	PH S 1	PH S2&3	DO mg/l S 1	DO mg/l S 2	DO mg/l S 3
1	Mon	3000		980	940	3	14.0	6.9	6.9	1.4	6.4	3.6
2	Tue	2750	1790	980	940	3	15.0	6.9	6.9	1.4	6.4	3.6
3	Wed	3000		980	953	3	15.0	9.5	9.5	3.7	7.2	7.2
4	Thu	3200		980	886	3	16.0	8.7	8.7	6.4	10.8	4.3
5	Fri	2500		960	770	3	14.0	8.3	8.2	4.5	6.3	9.8
6	Sat	2500		960	77	03	13.0	8.3	8.2	4.5	6.3	9.8
7	Sun	2900		975	890	3	16.0	7.6	7.6	6.	09.8	4.0
8	Mon	2800		970	770	3	15.0	8.1	7.8	5.7	10.0	3.9
9	Tue	2800		970	860	3	15.0	8.0	7.9	3.1	8.7	3.5
10	Wed	2800	1550	980	850	3	15.0	8.2	7.7	3.3	8.5	3.6
11	Thu	2620	1490	970	880	3	15.0	7.8	7.9	4.2	8.1	4.0
12	Fri	3180	1430	990	960	3	14.0	11.2	11.2	6.7	11.3	4.1
13	Sat	3000		920	720	3	16.0	9.0	9.2	5.4	10.6	4.4
14	Sun	3600		980	7000	3	16.0	8.5	8.5	3.4	8.9	4.2
15	Mon	5120	2080	970	880	3	16.0	8.3	8.1	2.6	8.6	4.0
16	Tue	5120	1080	970	880	3	16.0	8.3	8.1	2.6	8.6	4.0
17	Wed	3610	1570	960	550	3	18.0	7.8	7.5	3.9	9.0	4.6
18	Thu	3320	1460	850	500	3	18.0	8.0	7.8	3.2	7.8	5.0
19	Fri	4290	1780	920	610	3	17.0	7.4	7.3	2.0	6.8	4.7
20	Sat	4000		940	620	3	18.0	7.0	7.0	2.4	6.3	4.0
21	Sun	4000		960	760	3	18.0	6.8	6.9	4.0	5.3	6.0
22	Mon	2800		930	690	3	19.0	7.3	7.2	1.8	4.9	6.0
23	Tue	4160	1940	940	710	3	20.0	7.3	7.1	8.4	6.6	6.1
24	Wed	3990	1910	920	950	3	20.0	7.4	7.2	2.4	6.0	6.6
25	Thu	4070	2020	940	640	3	19.0	7.6	7.4	5.4	6.6	6.9
26	Fri	3910	1960	950	670	3	18.0	7.1	6.9	4.2	6.0	7.5
27	Sat	4500		960	750	3	20.0	7.3	7.2	3.0	6.2	7.8
28	Sun	5300		960	760	3	20.0	6.7	6.7	3.2	7.6	8.0
29	Mon	4800		960	720	3	20.0	6.8	6.7	3.0	3.4	6.3
30	Tue	3830	2030	930	700	3	20.0	6.6	6.6	2.5	3.7	7.2
Average		3582	1792	955	976	3	16.9	7.8	7.7	3.6	7.4	5.5
Median		3600	1910	960	770	3	16.0	7.8	7.6	3.3	7.2	4.7
Minimum		2500	1430	850	500	3	13.0	6.6	6.6	1.4	3.4	3.5
Maximum		5300	2080	990	7000	3	20.0	11.2	11.2	6.7	11.3	9.8

Figure 16 (Cont'd)

FT. GEORGE G. MEADE AWT FACILITY

Preventive Maintenance Scheduled for MAINTENANCE

SEQ NO	UNIT ID	COMPONENT TYPE	PLANT LOCATION	TASK DESCRIPTION	PM TASK ID	PM LAST PERFORMED (date)	(hours)	PRIORITY	SMP NUMBER	TIME (min)
						SOCKET AND RACHET SET				
142	PPS-0002	GEAR REDUCER	9581-B	CHANGE LUBE IN GEARED REDUCER CHECK GEAR TOOTH CONDITION AND CONTACT PATTERN *CONSULT O & M FOR MORE SPECIFIC INSTRUCTIONS***** BE SURE TO CHANGE LUBE IN ALL PARTS OF REDUCER	RD-515A-1	03/06/1984 EP GEAR LUBE #6 OIL GALLON OIL CAN OIL FUNNEL / FLEXHOSE SPENT OIL CONTAINER 12-INCH CRESENT WRENCH WIPE DOWN RAGS 20-FOOT LADDER SOCKET AND RACHET SET	65.1	1.2-C CAUTION--LOCKOUT POWER SOURCE PRIOR TO PM TASK NOTE: BE VERY CAREFUL AROUND HYDROCHLORIC ACID TANK AND SECURE LADDER.		30
143	PPS-0002	GEAR REDUCER	9581-B	CHANGE LUBE IN GEARED REDUCER CHECK GEAR TOOTH CONDITION AND CONTACT PATTERN *CONSULT O & M FOR MORE SPECIFIC INSTRUCTIONS***** BE SURE TO CHANGE LUBE IN ALL PARTS OF REDUCER	RD-515B-1	03/06/1984 EP GEAR LUBE #6 OIL GALLON OIL CAN OIL FUNNEL / FLEXHOSE SPENT OIL CONTAINER 12-INCH CRESENT WRENCH WIPE DOWN RAGS 20-FOOT LADDER SOCKET AND RACHET SET	65.1	1.2-C CAUTION--LOCKOUT POWER SOURCE PRIOR TO PM TASK NOTE: BE VERY CAREFUL AROUND HYDROCHLORIC ACID TANK AND SECURE LADDER.		30
153	LTC-0001	GEAR REDUCER	9581	CHANGE LUBE IN GEARED REDUCER CHECK GEAR TOOTH CONDITION AND CONTACT PATTERN *CONSULT O & M FOR MORE SPECIFIC INSTRUCTIONS***** BE SURE TO CHANGE LUBE IN ALL PARTS OF REDUCER	RD-5400-2	03/06/1984 EP GEAR LUBE #6 OIL GALLON OIL CAN OIL FUNNEL / FLEXHOSE SPENT OIL CONTAINER 12-INCH CRESENT WRENCH WIPE DOWN RAGS 20-FOOT LADDER SOCKET AND RACHET SET	4.7	1.2-C CAUTION--LOCKOUT POWER SOURCE PRIOR TO PM TASK NOTE: BE VERY CAREFUL AROUND HYDROCHLORIC ACID TANK AND SECURE LADDER.		30
154	MIX-0015	GEAR REDUCER	9581-B	CHANGE GEAR CASE OIL AND LUBE LUBE SHAFT COUPLING AND EXPELL OLD GREASE REPLACE PLUGS AND WIPE DOWN COUPLING CHANGE GEAR CASE OIL WITH PARADENE 150 R&O OIL CHECK OPERATION OF UNIT FOR ABNORMAL SIGNS OF WEAR PLAN RUST PREVENTION AND PAINT **NOTE** TAKE EXTREME CARE ON TOP OF POLYMER TANKS. POLYMER AND WATER MAKE A VERY SLIPPERY SURFACE AND PROVIDE A CONDITION OF HAZARD WHEN WORKING SO FAR FROM THE FLOOR.	RD-5410-2	03/06/1984 PARADENE 150 R&O OIL GALLON OIL CAN OIL FUNNEL SPENT OIL CAN WIPE DOWN RAGS MECHANICS TOOLS PYROPLEX EP2 GREASE GREASE GUN GREASE FITTINGS	3025.7	1.2-C CAUTION--LOCKOUT POWER SOURCE PRIOR TO PM TASK		15
155	MIX-0016	GEAR REDUCER	9581-B	CHANGE GEAR CASE OIL AND LUBE LUBE SHAFT COUPLING AND EXPELL OLD GREASE REPLACE PLUGS AND WIPE DOWN COUPLING CHANGE GEAR CASE OIL WITH PARADENE 150 R&O OIL CHECK OPERATION OF UNIT FOR ABNORMAL SIGNS OF WEAR PLAN RUST PREVENTION AND PAINT **NOTE** TAKE EXTREME CARE ON TOP OF POLYMER TANKS. POLYMER AND WATER MAKE A VERY SLIPPERY SURFACE AND PROVIDE A CONDITION OF HAZARD WHEN WORKING SO FAR	RD-5420-2	03/06/1984 PARADENE 150 R&O OIL GALLON OIL CAN OIL FUNNEL SPENT OIL CAN WIPE DOWN RAGS MECHANICS TOOLS PYROPLEX EP2 GREASE GREASE GUN	3025.7	1.2-C CAUTION--LOCKOUT POWER SOURCE PRIOR TO PM TASK		15

Figure 17. PM scheduled for maintenance report from M&E system at Fort Meade.

Prior to installation of the computer-aided O&M system, the Fort Meade AWWTF used a card system (see in Chapter 3) for equipment maintenance; however, the construction of the new plant with 500 pieces of equipment made the card system obsolete. Since many treatment units can be offline at times, the computer automatically keeps track of equipment use. If performed manually, the same task would be extremely cumbersome. Overall, the Fort Meade AWWTF management personnel are getting more out of the computer-aided O&M system than their counterparts at Fort Sill.

The standard package of the M&E computer-aided O&M system was almost fully implemented at Fort Meade. The operation system RODA was nearly 100 percent implemented, with some special features created for Fort Meade and Army regulations. Routinely, three peripheral sheets were used to manually collect operation, sampling, and solids handling data. At the end of the day, a staff member would summarize the data onto a RODA data entry sheet. The data were entered into the computer periodically. On the average, 5 minutes/day were required for operational data entry into the computer. To illustrate the advantage of using the RODA program, 2 hours and 40 minutes are required to generate the 14-page special monitoring report for submission to the Army each month (including time for data entry and report generation). Doing these tasks manually would require an estimated 4 to 5 mandays.

The RODA program was used much more often than COPE. The plant staff estimated about 1 hour/day computer use, of which 70 percent was for the RODA operation program. Even though many more program elements were implemented in COPE than in RODA, COPE was used less frequently. Preventive maintenance was normally done once a month and updated about four times/month at most. PM tasks was done for all equipment down to laboratory equipment calibration, checking of fire extinguishers, and checking of weatherproof switches. Because the plant was relatively new, corrective maintenance occurred infrequently. About 95 percent of the COPE program use was for PM.

Fort Meade Conclusions

The treatment plant staff's training in the use of RODA and COPE appeared to be adequate. Personnel felt that COPE was more complicated to use. The staff member who was most familiar with the system had to refer to the manual often.

M&E has been very cooperative with the Fort Meade AWWTF staff. They responded promptly to requests for system information, program modification, and problem solving with the hardware and software systems. System enhancements and updates were passed along at no cost. The staff has accepted the computer-aided O&M system and uses it routinely. While a cost savings demonstration is not yet feasible, the staff does recognize the system as an efficient and useful management tool. The features that impress them most are: (1) fast data retrieval that allows the observation of plant performance at any time or for any time period, (2) chemical and utility use and their changes with flow or season, and (3) PM performed and backlogged for scheduling.

As with Fort Sill, the software did not include report formatting, so users could not add, delete, or change report parameters. They must therefore rely on the software contractor for these services.

Lessons Learned

Analysis of experience to date with computer-aided O&M systems in Army WWTF applications enabled researchers to evaluate the systems with regard to Army applicability, vendor selection, and qualification of plant staff.

Army Applicability

For a small facility like the Fort Sill WWTP without complex treatment processes, the need for using a computer-aided O&M system is questionable, because large cost savings are unlikely. Since the present staff is already small, there is no possibility of reducing its size. However, a computer-aided O&M system could improve productivity, minimize equipment downtime, and keep the staff constantly aware of plant activities so that more timely preventive and corrective steps can be taken. Justifying the system is less demonstrable for this plant because it has been well managed and has performed well in the past. However, such a system is likely to prove to be a desirable tool that will result in continued NPDES compliance.

The Fort Meade AWWTF has completed its first year of system installation/implementation/training (October 1982 through October 1983) and 1½ years of routine system use (November 1983 through May 1985). The previously mentioned savings (p 58) amount to 3.67 to 4.67 mandays per month.

Larger plants, or small, sophisticated ones like the Fort Meade AWWTF, can realize more benefits. So far, experience indicates a fair amount of computer use and savings in staff time and effort. As the Fort Meade facility requires more maintenance efforts with age (e.g., more equipment repairs), computer use will increase and the need will be even more obvious. Plant managers appreciate the system because they can obtain information quickly on the equipment history, the open work orders, available and backlogged manhours, and parts inventory. This information not only makes the manager knowledgeable about the condition of his/her plant, but makes a budget request much easier to prepare.

Vendor Selection

It is preferable to award a contract to a vendor on a turnkey project basis to ensure hardware-software compatibility and smoother system installation. Vendors who may have experience with municipal plants should modify and streamline their software for Army use before they install the system. At Army facilities, more time should be spent on training which should include the instruction in file formatting so that report parameters can be added, deleted, or changed. More hands-on training and extensive customization of the program will win system acceptance from treatment plant staff.

Qualification of Plant Staff

Some treatment plant staff, whether civilian or military, are apprehensive about using computers, even though all software has user-friendly languages. At the Fort Meade AWWTF, two members of the staff have had some college-level training in computer science. They accepted the system and became the most frequent users. Program implementation may require less time when operators of suitable background are available. They are also more patient with the program, willing to experiment with it, and make suggestions to the software vendor-contractor about needed plant-specific modifications.

7 GUIDELINES FOR COMPUTER-AIDED O&M SYSTEM SELECTION FOR U.S. ARMY APPLICATIONS

Questions basic to all Army Facility Engineers considering use of computer-aided O&M systems in Army treatment plants are:

1. When and where should a computer-aided O&M system be considered for Army application?

2. What is the most appropriate system for a specific application?

3. Should a "canned" program be considered as an alternative?

4. What is the appropriate approach to system procurement?

This chapter provides answers to these questions. Even though the systems may change and be more powerful in the future, the selection guidelines will always be pertinent.

When and Where Should a Computer-Aided O&M System Be Considered for Army Applications?

Many Army-owned water or wastewater treatment facilities are well designed and properly operated and managed. With enough properly trained staff, the treatment facilities produce good-quality effluent consistently. Unless staff reduction is likely, there is no need for a computer-aided system.

A computer-aided O&M system can be considered for Army applications in any one or combination of the following conditions:

1. A new facility with a designed capacity of 4 to 5 mgd of daily dry-weather flow or higher which requires secondary or better treatment

2. A facility expanded and upgraded to an extent that more staff must be added and the existing crew needs further training, and/or

3. An existing plant with consistent difficulty in treatment compliance, where the major factor contributing to the difficulty has been identified as O&M deficiencies.

Table 6 summarizes these conditions.

For a new facility with 4- to 5- mgd flow providing secondary or better treatment, the complexity of the treatment processes requires careful monitoring and the collection of a multitude of operational data for analysis. Thus, the successful operation of a treatment plant demands considerable effort and manhours. Furthermore, a great deal of effort is also required to maintain the large amount of equipment in workable condition. Much time is required to schedule preventive and corrective maintenance, issue and track work orders, and maintain a proper inventory of parts. Different reports need must be prepared for the manager to oversee the plant operation and maintenance, keep the historical records, report to regulating agencies, and answer to various unscheduled demands. This is where a computer-aided O&M system can be applied

Table 6

Summary of Cases When Use of Computer-Aided O&M is Recommended at Army Wastewater Treatment Plants

Type of Plant	Computer-Aided O&M System recommended	Cost Saving	Data Collection for maintenance system input
1. New, 4-5 mgd or larger, secondary or better treatment.	Yes	High rate of return. Savings of ½ to 1 man-year per year.	Should be carried out by plant personnel to eliminate extra cost.
2. Expanded or upgraded, needs additional staff.	Yes	Same as above.	Same as above, or outside contractor
3. Existing plant with consistent O&M deficiencies causing noncompliance.			
a. Plant small, staff sufficient to handle modified O&M procedures.	No (see "canned" program alternative in this chapter).	Not applicable.	*Not applicable.*
b. Staff addition required to handle modified O&M procedure.	Yes	Same as 1 or 2	Either by plant personnel or outside contractor.

beneficially. As long as the necessary data are collected, the computer can perform the work associated with data analysis (scheduling the PM and CM works, controlling parts inventory, preparing reports, and informing the manager of the direction in which the treatment plant operation is going) in a small fraction of the time required by a manual system. The cost justification for the computer-aided O&M system (Chapter 3) indicated a saving of 1/2 to 1 man-year, depending on the size of the plant.

For an expanded and upgraded plant requiring additional staff, the same justification used for a new facility applies. The cost justification also remains the same. However, one other benefit can be realized in this application. With the upgrading and expansion of the plant, the existing crew, from the supervisor on down, may need further training to operate and manage the plant. They can receive this

training by taking courses or by working with crews of other plants similar to the upgraded facility. However, during negotiations with the software vendors and the subsequent system customization/installation, there is a good opportunity for the plant's key personnel to talk extensively with experts representing the vendor. Useful information and suggestions can be obtained on how to operate and maintain the plant (including data collection requirements, analyses, and report design helpful for work supervision and management).

For an existing plant that consistently has difficulty meeting performance standards mainly because of O&M deficiencies, there must be a major revision of O&M procedures. The plant manager faces two alternatives: (1) overhaul the O&M procedure, but retain a manual system or (2) install a computer-aided O&M system. The facility most likely needs help from an outside consultant to identify deficiencies and to recommend modifications. The recommendations may include adding staff. If the plant is small and the existing staff can handle the new O&M procedures, a manual system can be kept. On the other hand, if the newly recommended O&M procedures are elaborate, reflecting the complexity of the plant, a computer-aided O&M system will be beneficial, regardless of whether more staff is recommended.

If no more staff is required, the installation of a computer-aided O&M system represents an extra capital investment and annual O&M cost for the plant. If more staff is needed, the installation of the computer-aided O&M system will provide substantial savings identical to the previously presented cases.

The cost of collecting data for the maintenance program installation (equipment manufacturers, model number, parts, PM requirements, location, etc.) has not been considered so far. The cost varies significantly, depending on the size of the plant, equipment records of an existing plant, and who collects the data. An old plant is likely to find that equipment records are missing or incomplete. Substantial amounts of labor are required for data collection. For a new plant, the task is simpler. Plant personnel who are most knowledgeable about where records are kept and where the equipment is can collect the data, particularly for newly built plants. The vendor will provide the necessary forms for plant personnel to fill in the data being collected so it can easily be input into the program. An operator at the Fort Meade wastewater treatment plant spent about 4 months working 10 hours per week collecting all the maintenance data for input. At that time, the plant was new and records/manuals of equipment were well kept. On the other hand, the Fort Sill treatment plant is old and was recently upgraded. Much of the equipment being used is old, and records and manuals for it are incomplete. An outside consultant spent about 28 mandays to collect the maintenance data.

What Is the Most Appropriate System for a Specific Application?

Computer-aided O&M programs are available for operation, maintenance, or both. Some plants already have a good maintenance program, but need the operation program to help the supervisor and his/her crews operate the plant more efficiently and reliably. Both the Woonsocket treatment plant in Rhode Island and the Southington treatment plant in Connecticut are in this category. Fort Meade plant personnel use the maintenance program more often, although they have both programs. Therefore, the specific Army facility must decide if either one of the two programs or both should be implemented. With the installation of the hardware and one program, the second program can be added later. Vendors usually offer a discount price if the client purchases both programs at the same time.

How does a Facility Engineer choose among the various vendors offering computer-aided O&M systems? The best way is to ask for a demonstration in the store or at plants with treatment processes and size very similar to the facility in question. Comparing what each vendor can do in terms of program, cost, contract terms, and acceptance by clients (direct contact with their clients) will indicate the best candidate.

Many consultants have experience with using microcomputers in treatment facilities, and can help select the hardware/software system best suited to a facility's needs. However, limited knowledge of or inexperience with microcomputers should not necessarily prevent Army Facility Engineers from selecting a system. It is crucial, however, that decision-makers have a good understanding of their needs, and then look for the software and equipment that meet those needs.

It is useful to write down selection considerations and criteria, which will probably include the following:

1. The unit processes of the treatment plant and the number of parameters in the routine and periodic data collection

2. The reports to be generated and the amount of data to be included in the reports

3. The number of pieces of equipment that will be included in the maintenance file and the data to be stored for each item; if there is an existing manual cardfile, this can be used as a guide

4. Number of items to be included in the spare parts inventory and the amount of information to be stored for each item

5. The programming language(s) under which the system will operate (most commonly accepted ones are CP/M, PC/DOS, MS/DOS)

6. Printer speed, form size, and print quality requirements

7. Desired graphic capability

8. The ability to communicate with a large computer facility (helpful but not critical)

9. The expandability of the microcomputer to have an adequate number of unoccupied I/O ports and interfaces available for future expansion to include an on-line monitoring feature (helpful but not critical).

The vendors who meet all these needs should be evaluated by the following criteria:

1. Demonstration of the proposed computer-aided O&M system in a similar plant, perhaps with examples from your plant record. Are programs easy to operate? Are input/output steps simple and easy to follow?

2. Is the manual clearly written, complete, and easily understood?

3. Does the program require a large, elaborate user's manual, or is it designed to be "user friendly"? In other words, will the user need to constantly refer to the user's manual, or does the program prompt the user with questions or "menus" displayed on the screen?

4. Problem-solving experience of the vendor and acceptance of the program by his/her clients.

5. Availability of continuing support (debugging, repair, program enhancement) from the vendor and the cost of that support.

6. Extent of user training provided.

7. System package cost including or excluding hardware.

The Army Facility Engineer can assign points to each of the seven evaluation criteria (e.g., one point for not favorable, two points for average, three points for very favorable). By summing the points for each vendor, it is possible to rank the vendors and select the most favorable one.

It is important to realize that except for small "canned" programs that are sold outright, all other programs tend to be customized. The program elements in each package are tailored to the user's needs. More importantly, the nature of the program element reflects the knowledge and experience of the vendor who modifies the database management system for his/her customer's use. Consequently, all these systems share some common features which are standard for treatment plant process control and maintenance; however, at the same time each system has some program element that differs from the other systems. These systems are by no means static. Each vendor will add on more special program elements to meet customer needs as the market expands. Thus, the program features presented in this chapter for comparison reflect only the current system capability and client needs. A few years from now it is likely that each system will have expanded to include more program elements.

Appendix D compares O&M systems offered by four manufacturers. It provides useful information for deciding what O&M features are important for a given plant and which O&M system(s) have those features.

Should a "Canned" Program Be Considered as an Alternative?

"Canned" software is already programmed and cannot be adapted uniquely for any one plant. It is less costly than customized software, but may have limited uses. Canned software usually does not come with a warranty or services to update the system later. Although it cannot be tailored to each plant, some programs can still handle a large amount of information. Jentech is one firm that offers this type of program. Despite the fact that their software costs less than $900, the program allows input of 500 pieces of equipment, 1200 work order histories of 70 characters each, 1600 inventory parts, and 1200 job descriptions. Sufficient instruction is provided in a manual for users to input the necessary data and output the various PM reports, work history, inventory reports, and manufacturer information. The program is compatible with inexpensive hardware (Apple IIe computer with floppy disk drive and compatible monitor, and printer). Although not comprehensive, the program has most of the main features of other maintenance programs. If the treatment plant has the Apple II microcomputer, the Jentech maintenance program is a very cost-effective investment. While Jentech does not offer after-sale service and program enhancements, an 800-line telephone number is given so that users may obtain some limited technical advice. The Apple II microcomputer is also used for the Cochrane Inc. TREDAT operational management program. Consequently, it is a viable alternative for treatment facilities to install a computer-aided O&M system using the Apple IIe computer in combination with TREDAT

of Cochrane Inc. and the Jentech Maintenance program. Such a system is most suitable for small to medium-sized plants. Cochrane Inc. has also made a maintenance program available recently (TREMAIN), but it is much more expensive than the Jentech program.

An Apple II microcomputer is useful for the ES Environmental Services Diagnostic Operational Program for periodic plant evaluation rather than for daily use at a plant. Other small programs using the Apple II microcomputer include Gannett Fleming Environmental Engineers, Inc., POTW Performance Compliance diagnostic program, and Process Control Software's Sludge Master Utility Disk #1.

"Canned" programs could be valuable to small/medium-sized treatment facilities where limited program functions are adequate and there can be a low investment in system cost. However, it should be noted that off-the-shelf software does not provide training. Users must have more initiative and more patience to go through the self-learning period for such applications.

How Do You Negotiate for a Contract?

Once a vendor is selected, it is wise negotiate a contract that will protect the buyer. Wilkes[14] has provided a checklist that should be covered in a software contract with a vendor.

1. Ownership Software:
   a. Will you own or merely license the software?
   b. Does the software contract limit the licensee from using the software for its subsidiaries, affiliates, or joint venture clients?
   c. Is the software limited to one processor (CPU) or can it be used on other equipment within the Army facility's possession?

2. Continuing Support:
   a. What is the nature/scope of the continuing software support? At what cost?
   b. What is the warranty period? What does it cost for service after the warranty period?
   c What procedures for documenting and correction of bugs are in place? What are the responsibilities of the user and the vendor?
   d. Will the user be permitted or required to modify and correct the software?
   e. If so, what effect does this have on the warranty and on-going support of the software?
   f. Are source code (actual program instructions) and file definitions available? Directly to the user or in escrow? Additional cost?

3. Documentation and Training:
   a. Outline contractual obligations for delivery, creation, and on-going updates for both the technical and user documentation.
   b. What training is included? Are they on-site or informal classes, or both? Are there related additional costs?

4. Volumes Established and Guaranteed: Attach a volume statistics fact sheet to the contract so that the hardware/software to be used will accommodate the applicational volumes documented by the user and the vendor.

---

[14]B. Wilkes, "Contracting for Software," *Civil Engineering, ASCE* (January, 1984).

A well documented and well thought out contract will minimize litigation if problems arise. Litigation can lead to long delays in the work and can be costly.

What is the Appropriate Approach to System Procurement?

The Army Facility Engineer should be familiar with information in a USA-CERL document[15] on microcomputer selection if he/she considers the system requisition. This document provides background information on microcomputer characteristics and some general information on software, as well as a procurement procedure.

Selecting the software that meets all the user's needs is the most important factor. Next most important is selection of compatible hardware. The software vendor knows the best compatible hardware system based on his/her knowledge and experience of the treatment plant application using the software. If possible, the software/hardware system should be procured as a package. If this is impossible due to the government discount price applicable to hardware but not software, it is very important to purchase the entire hardware package through one vendor (specifications of CPU and other peripherals supplied by the software vendor). If the CPU and other components or peripherals are going out for bid as individual items, the chances of getting incompatible parts and components are very high. In other words, the user should get the lowest price offer for the entire package strictly according to specifications, not the lowest price for individual components. Even if the components are all compatible, items purchased from different sources will arrive at different times. By the time the last component arrives, the warranty period of the components that arrived earlier may have run out. If one component is not working, extra cost and further delay of work are inevitable.

The procurement procedure as it appears in USA-CERL Technical Report P-146 is given below. Note that if the facility's proposed hardware/software system is on the General Services Administration (GSA) schedule, procurement through GSA vendors is the obvious choice. If the software package is not on the GSA schedule, it is possible to procure the hardware through GSA vendors and the software on sole source or competitive bid. Ranking of vendors and the documents submitted by these vendors will be helpful in preparing sole source or competitive procurement.

Two things have happened since the first edition of this guide was published that have greatly affected on procurement strategies for microcomputer hardware and software for construction field offices:

1. The GSA has negotiated a Multiple Award Schedule Contract (FSC Group 70, Part 1, Section C Schedule) with many vendors to supply microcomputer systems to the Government at a substantial discount.

2. Engineer Regulation 415-1-12 has been issued,[16] which strongly recommends the use of GSA Section C for procuring microcomputers whenever possible.

---

[15]M. J. O'Connor, T. A. Kruppenbacher, and G. E. Colwell, *Microcomputer Selection Guide for Construction Field Offices* Technical Report P-146 (Revised)/ADA146615 (U.S. Army Construction Enineering Research Laboratory, 1984).

[16]ER 415-1-12, *Field Office Use of Microcomputers* (Office of the Chief of Engineers, 8 June 1984).

Purchasing hardware and software through GSA is competitive procurement, which allows the buyer to specify products by proprietary name, model number, etc. Purchasing from the GSA schedule also reduces procurement cycle time; the time otherwise required to prepare specifications, advertise for bids and evaluate them is saved.

The use of GSA vendors can reduce the time for actual procurement, but first, funding must be identified and procurement approval obtained.

Funding

The following discussion of funding is taken from ER 415-1-12.

Microcomputer Purchase

1. The Plant Replacement and Improvement Program (PRIP) is generally the primary funding source for microcomputer purchases. Purchase via PRIP requires close coordination with District and possibly higher-level Corps of Engineers comptrollers. Monthly reimbursement of the PRIP revolving fund is required from project funds. Some exceptions to this general rule are:

a. Microcomputers which will be used *exclusively* for civil works projects may be purchased with project funds. The Civil-Appropriated Construction General or Operations and Maintenance (96 x 3122 and 96 x 3123 respectively) funding sources apply in this regard.

b. Europe, Japan, and Far East will use their Carrier Fund.

c. Microcomputers for projects totally funded by other than DOD agencies (Saudi Arabia, Department of Energy, NASA, and other) may be purchased with project funds.

2. Other Procurement, Army (OPA) funds are a possible source of money when the microcomputer system(s) will be used solely on military projects. Yearly OPA funds requests for ADP equipment are normally prepared by the District ADP Coordinator. Note that OPA funds cannot be assured and there may be long lead times.

3. Other sources are sometimes available on special occasions as initiated by Headquarters, Department of the Army (HQDA). An example is the Quick Return on Investment Program (QRIP), which is a special solicitation by HQDA. QRIP funding cannot be assured; however, field input for possible funding is encouraged where possible long lead times and delays will not adversely impact procurement.

Other Support Requirements

1. Maintenance. Maintenance of microcomputer hardware after the warranty period, and software maintenance as required, will be funded by the S&A account or other applicable project operating funds.

2. Software and Peripheral Devices. PRIP, OPA, S&A account, or other applicable project operating funds may be used to procure software and additional peripheral equipment. Standard peripheral devices should be included in the initial acquisition and will not be incrementally purchased to avoid using the PRIP revolving fund account.

Procurement Process

The two main avenues of acquisition are competitive and sole source.

Competitive

Competitive procurement is preferred because it gives the Government the advantage of lower price due to marketplace competition. Competitive acquisition may be employed in two ways. First, analyze the facility's needs, identify the appropriate system configuration, evaluate the various systems capable of meeting those requirements, and select a system that produces the best cost/benefit ratio. Then:

1. If the identified products are available through the GSA schedule, the system should be purchased from the GSA contractor, using the GSA-prescribed procedures.

2. If the identified products are *not* available through GSA schedules, the user must prepare performance specifications, advertise for competitive bids, evaluate the proposals received, and issue a contract to the successful bidder.

Sole Source

Sole source procurement will normally only be approved for additions to existing systems where there are overriding compatibility considerations. Justification for sole source procurement is required in accordance with the requirements of Army Regulation 18-1.[17] The IBM PC and PC-XT are now on the GSA schedule and hence do not require sole source justification.

Procurement Time

Procurement time will vary, depending on organizations and the procurement procedure used (e.g., GSA, sole source, or competitive bid), so the user should consult his/her ADP coordinator for a realistic estimate of procurement time. Plans should take into account that it may be several months from the time requirements assessment begins until the microcomputer system is delivered.

---

[17]AR 18-1, *Army Automation Management* (Department of the Army, 15 August 1980).

8 SUMMARY AND CONCLUSIONS

An evaluation of the use of microcomputer-based O&M systems at water/wastewater treatment plants showed that this technology could best be exploited at Army facilities when used for management of process control, trend analysis, report preparation, and preventive maintenance management.

Adoption of microcomputer-based O&M systems would be most beneficial in the following applications: new or large (4 to 5 mgd or greater) water or wastewater treatment plants; facilities that are being expanded or upgraded with advanced processes requiring a great deal of data collection and analysis; and facilities having trouble meeting discharge limits due to inadequate operation and maintenance. For plants not in these categories, other alternatives, such as a preventive maintenance program, more operator training, or maintaining a spare parts inventory, may be more appropriate.

Information has been presented on types of systems available and their advantages, disadvantages, and costs; factors that must be considered when selecting software, hardware, and a contractor; procurement steps; and lessons learned from field demonstrations of microcomputer-based O&M at two Army plants. Guidance was then presented for helping plants considering microcomputer-based O&M systems to evaluate the various options.

CITED REFERENCES

Army Regulation 18-1, *Army Automation Management* (Department of the Army, August 1980).

"Costly Wastewater Treatment Plants Fail to Perform as Expected," GA/CED-81-9 (U.S. General Accounting Office, November 14, 1980).

DOD Can Make Further Progress in Controlling Pollution From Its Sewage Treatment Plants, GOA/NS1AD-84-5 (U.S. General Accounting Office, February 3, 1984).

Davis, R. A. and J. L. Daugherty, "Computers Finally Aiding in Cost-Effective Operations, Deeds and Data," *Water Pollution Control Federation Journal* (May 1982), p.9.

Engineer Regulation 415-1-12, *Field Office Use of Microcomputers* (Office of the Chief of Engineers, 8 June 1984).

Federal Guidelines Operation and Maintenance of Wastewater Treatment Facilities (U.S. Environmental Protection Agency, August 1974).

Graham, E. U., *WSSC/WPCF Computer Applications Survey* (Washington Suburban Sanitary Commission, March 1984).

Guarino, C. F., and J. V. Radziul, "Data Processing in Philadelphia," *Water Pollution Control Federation Journal*, Vol 40, No. 8 (August 1968), p. 1383.

O'Connor, M. J., T. A. Kruppenbacher, and G. E. Colwell, *Microcomputer Selection Guide for Construction Field Offices*, (Revised) Technical Report P-146 (U.S. Army Construction Enineering Research Laboratory, 1984).

Pantages, A., "The Case for Computerization," *Pollution Engineering* (January 1984).

Reid, G. W., A. L. Law, and G. P. Chou, *Evaluation and Selection of Reliability and Maintainability of Water/Wastewater Treatment Technology for Military Application*, Final Report, Vol 1 (University of Oklahoma, August 1982).

Wilkes, B., "Contracting for Software," *Civil Engineering, ASCE* (January 1984).

UNCITED REFERENCES

Sullivan, D. L. and R. M. Monier, *Diagnostic Operational Modeling Programs for Municipal Wastewater Treatment Plants, User Manual* (October 1982).

U.S. General Accounting Office, "Treatment Plant Survey," *Water Pollution Control Federal Journal*, Vol 53, No. 2 (February 1981), p. 137.

APPENDIX A:

SURVEY OF COMPUTER APPLICATIONS IN WASTEWATER TREATMENT PLANTS*

Plant and Location	Operation System	Maintenance System	Point of Contact
	(I-Implemented	U-Under Development)	
Water Pollution Control P. O. Box 308 Huntsville, AL 35804	U		J. S. Dickinson, Supt. (205) 532-7515
91st Avenue WWTP Phoenix, AZ 85353	I		IDA Austin, Application Analyst (602) 936-7145
Morre, Knickerbocker Consulting Firm Phoenix, AZ 85353	U		Ken Knickerbocker, VP (602) 265-3776
East Bay Municipal Utility Oakland, CA 94623	U		Thomas Shastio Assoc. Env. Engr. (415) 465-3700
San Jose-Santa Clara WPCP San Jose, CA 95134	I		Mark Niver, Training Coordinator (408) 945-5300
CH2M Hill Engineering Consulting Firm Sacramento, CA 95814	U		Edward R. Schmidt (916) 441-3955
Big Dry Creek WWTP, Westminster, CO	I	I	Harry Briton Plant Supt. (303) 452-8010
Breckenridge Sanitation Breckenridge, CO 80424	I		L. J. Forrest, Collection Syst. Supt. (303) 453-2723
Metro Denver Sewage I Dist. #1 Denver, CO, 80229	I		Joan Nelson, Supt. of Operations (303) 289-5941

*from WSSC/WPCF Computer Application Survey, Washington Sanitary Commission, March 1984.

Plant and Location	Operation System	Maintenance System	Point of Contact
Metro Denver Sewage Dist. Denver, CO 80229	I		Dave Devanney, Data Processor (303) 289-5941
Persigo WWTP Grand Junction, CO	I	I	Jerry O'Brien Plant Supt. Terry Franklin Maint. Supt. (303) 244-2687
Snake River Wastewater Dillon, CO 80435	U		Roger Wenger, Oper. Dir. (303) 468) 468-5794
Lotepro Services Riverside, CT 06878	I	I	Robert Olt, Director 215 Riverside Ave. Riverside, CT 06878
HES Consultants Boynton Beach, FL 33435	U		Gary Hammond (305) 737-3718
City of Honolulu Honolulu, HI 96819	I		Thomas Fujiwara, Plant Engr. (808) 527-6801
City of Alton WWTP Alton, IL 62002	I		Jerold Olmstead, Supt.
City of West Chicago West Chicago, IL 60185	I	I	Michael Botts, Supt. (312) 231-3322
Metro Sanitary Dist. GRTR/CHGO Cicero, IL 60650	I		Donald W. Harper Coordinator of QC (312) 780-4061
North Shore Sanitary Dist. Gurnee, IL 60031	I		Bruce Snyder, Dir. Administrative Serv. (312) 623-6060
Thorn Creek Basin San. Dist. Chicago, IL 60411	I		Robert A. Davis Director of Oper. (312) 754-0525
U.S. Army CERL Fed. Govt. Champaign, IL 61820-1305	U	U	Lynn Ellen Lang, Engr. (217) 352-6511
Columbus Indiana Wastewater Plant Columbus, IN 47201			Garry Pugh, Chemist (812) 376-1021

Plant and Location	Operation System	Maintenance System	Point of Contact
Water Pollution Control Topeka, KS 66616		I	Raymond Stillwell, General Supv. (913) 235-9078
Terrebonne Parish Council, Houma, LA 70360	U		Al Levron, Supt. of Sewage (504) 868-3000
Howard Co. Dept. of Public Works Savage, MD 20763	I		Daniel Ward, Process Control Engr. (301) 792-7020
City of Jackson, WWTP Jackson, MI 49201	I		John St. Andre, Asst. Supt. Chemist (517) 788-4075
Metro Waste Control Comm. Eagan, MN 55123	I		Richard Arbour Interceptor System Mgr. (612) 454-7860
Kirkham, Michael & Assoc. Omaha, NE 68114	I	I	Robert Behaens, Process Analyst Consult. (402) 393-5630
H. W. Water Supply & Poll. Concord, NH 03301	U		Robert Livingston Asst. Chief Engr. (603) 271-3503
Ocean County Utilities Authority Bayville, NJ 08721	U		Richard Kunze, Admin. Asst. O&M (201) 269-4500
City of Lackawanna Lackawanna, NY 14218	U		Paul Pieczonka Chief Operator (716) 823-5800
Environmental Protection Agency Wards Island, NY	U		Robert Vellinger Industrial Waste Control Section
Lake Place Wastewater Lake Placid, NY 12946	U		Paul Gutmann, Chemist (518) 523-1581
Olean WWTP Olean, NY 14760	U		Donald Lyle, Chief Operator (716) 373-2175

Plant and Location	Operation System	Maintenance System	Point of Contact
Orange Water & Sewer Auth. Carrboro, NC 27510	I	I	Patrick Davis Systems Development Mgr. (919) 968-4421
Bowling Green WWTP Bowling Green, OH 43402	I		John Drescher, Supt. (419) 352-1704
Macola, Inc. Marion, OH 43302	U		Bruce Hollinger, Mgr. (614) 382-5991
City of Hermiston Hermiston, OR 97838	U		Don Caldwell, Supt. (503) 567-5272
City of Medford WQCP Central Point, OR 97502	I	I	Woodie Muirhead Supv. 1100 Kirtland Rd. Central Point, OR 97502
Hatfield TWP Municipal Municipal Authority Colmer, PA 1895	U	U	Coley Bundick, Maint. Supt. (215) 822-9300
Derry Twp Municipal Auth. Hershey, PA 17033	U	U	Barbara Brandt, Administrative Supv. (717) 566-3237
Philadelphia Water Dept. Philadelphia, PA 19153	I		C. O. Brown, Sanitary Engr. (215) 592-4014
Betz-Converse-Murdoch,Inc. Plymouth Meeting, PA 19462	I	I	Thomas May, VP (215) 825-3800
ECS, Inc. Bryn Mawr, PA 19010	I		Francis Frissors President (215) 527-1015
Gannett Fleming Engrs. Harrisburg, PA 17105	I		Albert Bain, Project Mgr. (717) 763-7211
Greeley and Hensen Philadelphia, PA 19103	I		Harold Gilnan, Associate (215) 563-3460
Drexel University Philadelphia, PA 19103	U		Yakir Hasit, Asst. Prof. (215) 895-2281
Phoenix Environmental Con. Nashville, TN 37212	U		Peter Shack, Pres. (615) 833-1332

Plant and Location	Operation System	Maintenance System	Point of Contact
City of Arlington Arlington, TX 76010	U		John Kubala, Dir. of Utilities (817) 275-3271
City of Sherman Sherman, TX	I		Thomas Miller Wastewater Supv. (214) 892-4545
City of Tyler Tyler, TX 75710	U	U	Monty Shawk, Water Quality Coordinator (214) 531-1239
Gulf Coast Waste Disposal Houston, Tx 77058	I	I	Leonard Levine, Sr. Engr. (713) 488-4115
Analytical Services Fort Worth, TX 76106	U		Irvin Lofton (817) 277-6930
Chesterfield County Chesterfield, VA 23832	U		David Welchons, Dir. of Utilities (804) 748-1401
Hampton Road San. Dist. Virginia Beach, VA 23455	U		Keith Benson (804) 460-2261
Biological Monitoring, Inc. Blacksburg, VA 24060	I		Chris Thompson, Chief Engineer (703) 953-2821
City of Bellingham Bellingham, WV 98226	U		Kenneth Thomas Operation Engr. (206) 676-6850
Lakehaven Sewer Dst. Federal Way, WA	I		Melva Yoder (206) 839-7441
Municipality of Metro Seattle Seattle, WA 9804	I	I	Curtis Leister, Systems Supv. (206) 447-6885
Pentree, Inc. Princeton, WV 24740	U		Wilbur Smith, VP (304) 425-9851
Howes Leather Co. Frank, WV 24937	U	U	Leonard Cook, Dir. (304) 456-4898

Plant and Location	Operation System	Maintenance System	Point of Contact
Marshfield W.W. Utility Marshfield, WI 54449	U	U	Ron Dickrell, Supt. (715) 384-4272
Milwaukee Metro Sewerage Milwaukee, WI 53202	U		Thomas Wolf, Dir. District Services (414) 225-2062
Walworth Co. Metro Sewage Delavan, WI 53115	I	I	Stephen Miller Process Control Supv. (414) 728-2653
Donohue and Assoc. Inc. Sheboygan, WI 53081	I	I	Keith Garneth, Pres. (414) 458-8711
CANADA			
City of Kelowna Kelowna, BC V1Y1J4	I	I	G.M. Stevens, Supt. (604) 762-4616
Control and Metering LTS Toronto-Ontario M9C1B2	I	I	Ahron Nahmias, Mgr. (416) 626-8411
Ker, Preistman & Assoc. Victoria, BC V8Y4M3	U		G. E. Giles, Environmental Engr. (604) 388-6676

APPENDIX B:

CUSTOMER LISTS

(Information made available by vendors as of December 1984)

Metcalf & Eddy, Incorporated

RODA

Name and Address of Client	Description of Facilities (Type, Size, Etc.)	Process Control Management Software Package	Computer Hardware in Use	Name and Phone Number of Client Contact
Fort George G. Meade, MD	Advanced Wastewater Treatment, 5.0 mgd	RODA-M	IBM personal computer	Duane Wilding Plant Superintendent (301) 674-5040
Sanitary District of Elgin, IL	Advanced Wastewater Treatment, 25 mgd	RODA-M	IBM personal computer	Al Pagorski, District Manager (312) 742-2068
Town of Warren, RI	Secondary, 2.5 mgd	RODA	PDP 1170 mainframe computer	Gil Carey (401) 245-4086
City of Fall River, MA	Secondary, 31 mgd	RODA-M	PDP 1170 mainframe computer	Vicktor Huliew Plant Superintendent (617) 672-4522
The Mattabasett District, Cromwell, CT	Primary, 20 mgd	RODA-M under	IBM personal installation computer	Christian Bratina (203) 635-5550
Town of Rockland, MA	Advanced Wastewater Treatment, 2.5 mgd	RODA-M under installation	PDP 1170 mainframe computer	Ron Laro (617) 78-1863
Town of Marlborough, MA	Advanced Wastewater Treatment, 5.0 mgd	RODA	PDP 1170 mainframe computer	John Hartley (617) 485-1755
Westchester County, New Rochelle WWTP New Rochelle, NY	Advanced Wastewater Treatment, 20.0 mgd	RODA	PDP 1170 mainframe computer	James Morris Director (914) 632-0660
Town of Smithfield, RI	Secondary, 1.7 mgd	RODA-M	IBM personal computer	Ernest Persechino (401) 231-6666

Metcalf & Eddy, Incorporated

COPE

Name and Address of Client	Description of Facilities (Type, Size, Etc.)	Maintenance Management Software Package	Computer Hardware in Use	Name and Phone Number of Client Contact
City of Allentown, PA	Tertiary, 40 mgd	Manual Card System	None	Dan Koplish, Plant Superintendent (215) 437-7641
Sanitary District of Elgin, IL	Advanced Wastewater Treatment, 25 mgd	COPE	IBM personal computer	Al Pagorski, District Manager (312) 742-2068
Department of Environmental Services, Washington, DC	Advanced Wastewater Treatment, 309 mgd	Manual Card System prototype COPE/M (microcomputer)	IBM personal computer	Paul Ragsdale (202) 767-7603
North Charleston Sewer District Charleston, SC	Secondary, 18 mgd	Manual Card System	None	Alan Ramsey, Sewer District Manager (803) 722-2657
Town of Warren, RI	Secondary, 2.5 mgd	COPE	PDP 1170 mainframe computer	Gil Carey (401) 245-4086
Town of Fall River, MA	Secondary, 31 mgd	COPE	IBM personal computer	Vicktor Huliuw Plant Superintendent (617) 672-4522
Mattabassett Sewer District	Primary, 20 mgd	COPE	IBM personal computer	Christian Bertina (203) 635-5550
Town of Rockland, MA	Advanced Wastewater Treatment, 2.5 mgd	COPE under installation	IBM personal computer	Ron Laro (617) 878-1863
Fort George G. Meade, MD	Advanced Wastewater Treatment, 5.0 mgd	COPE	IBM personal computer	Claude Donaldson (301) 674-5040

EOS Computer Installations and Full Operations and Maintenance Contracts

Client Name/ Type of Contract	Size and Level of Treatment	Length of Time the Computerized Process Control (PC) and Maintenance Management Systems (MMS) Have Been On-Line	Contact/Client
Fairfield-Suisun Manager Sewer District Fairfield-Suisun, CA Full O&M	15 mgd AWT 4 Pump Stations Energy Recovery Laboratory	PC: 3+ years MMS: 1+ years IBM PT XT, TRS-80 MII	PC: Larry Bahr, Asst. Plant (707) 429-3233 MMS: Kirk Howard, Maint. Supervisor Client Since 1974
Taunton, MA Full O&M	8.5 mgd AWT	PC: 3+ years MMS: 9 months TRS-80 MII	Tim Slattery, Plant Manager (613) 823-3893 Client since 1980
Great Falls, MT Full O&M	21 mgd PC: 2 years Secondary 26 Pump Stations Laboratory	MMS: 6 months TRS-80 MII	David Brown, Plant Manager (406) 761-7004 Client since 1977
Vancouver, WA Full O&M	13 mgd PC: 3+ years Secondary 4 mgd Secondary	MMS: Being installed 3/84 TRS-80 MII	Wade Weakley, Plant Manager (206) 696-0959 Client since 1978
Poughkeepsie, NY Full O&M	9 mgd PC: 3+ years Secondary TRS-80	MMS: 6 months Client since 1980	Doug Smith, Plant Manager (914) 471-8165

EOS Computer Installations and Full Operations and Maintenance Contracts

Client Name/ Type of Contract	Size and Level of Treatment	Length of Time the Computerized Process Control (PC) and Maintenance Management Systems (MMS) Have Been On-Line	Contact/Client
Gresham, OR Full O&M	10 mgd PC: 3+ years Secondary	MMS: Being installed TRS-80 MII	Mike Garrity, Plant Manager (503) 667-6289 Client since 1980
Leominster, MA Full O&M	8.6 mgd Secondary	PC: Being Installed MMS: Being Installed IBM PC XT (In startup)	Mike Sause, Plant Manager (617) 537-5720 Client since 1983
Harrison Co., MS Full O&M	25 mgd PC: 1 year (Total 5 Plants) Secondary	MMS: 6 months	Walter Cook, Plant Manager (601) 863-0324 Client since 1982
Petaluma, CA Full O&M	5 mgd AWT	PC: 2 1/2 years	Vic Vista, Plant Manager (707) 762-5892 Client since 1979
Burlingame, CA Full O&M	4 mgd AWT MMA: 2 months	PC: 2 years MMS: 2 months	Rawle Alloway, Plant Manager (415) 342-3727 Client since 1972
Sacramento Co., CA Full O&M	23 mgd Secondary 4 mgd Secondary	PC: 2 years	Client 1979-1982

EOS Computer Installations and Computer Service Contracts

Client Name/ Type of Contract	Size and Level of Treatment	Length of Time the Computerized Process Control (PC) and Maintenance Management Systems (MMS) Been On-Line	Contact/Client
Blue Piains Washington, D.C. Computer Services	320 mgd AWT	PC: 1 year TRS-80 M16, EBM PC-XT	Walter Bailey Wastewater Division Chief (202) 767-8208
Seattle Metro Computer Services	120 mgd Primary	PC: 5 months IBM PC-XT	Barry Uchida Process Control Supervisor (206) 447-6801 Client since 1983
Palo Alto, CA Computer Services	31 mgd AWT	PC: 8 months IBM PC-XT	Bill Miles, Assistant Supt. (415) 329-2598 Client since 1983
South Bayside Systems Authority Redwood City, CA Computer Services	25 mgd Secondary	PC: 3 months MMS: 3 months IBM PC-XT	Jim Bewley, Plant Manager (415) 591-1721 Client since 1983
San Antonio, TX Computer Services	100 mgd Secondary 25 mgd Secondary 25 mgd Secondary	PC: 2 months	Richard McNeill, Biochemical (512) 924-9492 Client since 1984
St. Petersburg, FL Utilities Dept. Computer Services	20 mgd Tertiary 20 mgd Tertiary 16 mgd Teritiary 16 mgd Tertiary 50 mgd Water Softening Plant 80 Wastewater Pump Stations	MMS: 2 months IBM PC-XT	William Johnson, Director of Utilities George Sutton, Maintenance Manager (813) 893-7261 Client since 1984

APPENDIX C:

SOFTWARE COSTS

The following summarizes software costs obtained at the time this report was prepared.

1. **Metcalf & Eddy (M&E)** — **Price**

   A. **Operations and Data Management (RODA):** — $11,500 to $17,000

This includes a one-time software licensing fee of $5000. This package includes:

- Exclusive rights to use the RODA program
- About 3 to 4 single- and multi-page operational reports (i.e., daily process control, monthly summary, utility consumption, and parameter exceedance), limited only by the client's imagination
- Between five and 10 trend analyses (graphic plots; also limited only by the client's imagination)
- Customized data input screens
- Complete user training
- Professionally written documentation.

The RODA program is warranted for 1 year against programming bugs and under most situations, all enhancements or updates are transmitted at little or no cost.

   B. **Maintenance Management (COPE):** — $10,000 to $25,000

COPE is an integrated database which has five unique programs:

1. PM scheduler
2. CM work order generation and tracking
3. Spare parts inventory
4. Equipment history
5. Equipment inventory.

A basic package would range between $10,000 and $25,000. This includes a one-time software licensing fee of $7500. The low side of this estimate would include:

1. Exclusive rights to use the COPE program
2. Complete user training
3. Complete set up training
4. Professionally written usable documentation.

The high side of this estimate would be typical if Metcalf and Eddy were required to assist more fully by establishing equipment codings, preventive maintenance requirements, spare parts requirements, and generally provide maintenance expertise to assist with detailed program organization onsite.

Like the RODA program, the COPE program is warranted for 1 year against programming bugs; enhancements or updates are usually transmitted at minimal or no cost.

Metcalf and Eddy offers complete support for both RODA and COPE. This support ranges from a RODA/COPE hotline to communications via a modem. They will also provide O&M specialists onsite to directly collect and enter all maintenance data in cases where no PM program currently exists and/or where onsite staff is limited.

		Price
2.	**Envirotech Operating Service (EOS)**	**Price**
A.	**Operation System:** Includes setup and user training.	$10,000
B.	**Maintenance System:** Assumes inventory, manuals, and equipment are reasonably well organized by plant personnel, and would not require Envirotech Operating Service to find equipment data or vendor information.	$15,000
3.	**Henningson, Durham & Richardson (HDR)**	**Price**
A.	**Lab Operation and Data Management:** Includes setup with about 1 week of labor.	$4000 to $45000
B.	**Operation and Maintenance Program:**	$3,000
	Initial training and setup	$2000 to $2500
C.	**Assembling Database for Maintenance Function:** Assumes manuals are handy, 500 pieces of equipment, 1 to 1.5 hr. labor per piece of equipment, including inputting, $40/hr labor rate.	$20,000 to $30,000

D. **Complete Turnkey With Everything Included:** Software, hardware, training, compilation of database, etc. (Depends on number of hours needed for database compilation and plant conditions). Price shown was reduced by the hardware cost obtained for this report (see Tables 2 and 3). — $25,591 to $35,591

4. **Cochrane, Inc.** — **Price**

A. **Data Handling:** Includes formatting, startup services, licensing, determining which calculated parameters are needed, training, and followup services. — $8,000 to $10,000

B. **Maintenance Program:**
1. Includes tailoring, start-up, training, inputting all information provided by client onto sheets. — $10,000 to $12,000*
2. If Cochrane must collect all information for data base, the price changes accordingly.* — $20,000 to $25,000

C. **Complete Turnkey w/Everything Included:** Software, hardware, training compilation of data base, etc. — $29,698 to $44,698*,+

*Depends on number of hours needed for database compilation and plant conditions.
+Price shown was reduced by the hardware costs obtained for this report.

APPENDIX D:

SYSTEM COMPARISONS

Capability or Feature	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Cochrane, Inc.
Type of plant that the system may be used on (RBC, liquid, air, Activated Sludge [AS,] etc.)	M&E will modify its operation program to suit any type of treatment plant.	EOS will modify its operation program to suit any type of treatment plant.	HDR will modify its operation program to suit any type of treatment plant.	Cochrane will modify its operation program to suit any type of treatment plant.
Maintains all daily data inputted and calculated parameters. Allows for quick retrieval and hard copy printout?	yes	yes	yes	yes
Organizes records for past/present?	yes	yes	yes	yes
Allows key parameters to be changed?	The firm may be requested to make the change for the user.	Parameters may be changed by the user when needed. Values may also be changed along with how parameters are calculated.	Ability to reconfigure plant data, report content, and format.	Parameters may be changed by the user when needed. Values may also be changed, along with how the parameters are calculated.
Identifies which units are online/offline?	Shows user which units are presently online. Helps eliminate unnecessary data entries.	Shows user which units are presently online. Helps eliminate unnecessary data entries.	N/A	N/A
Will print out all information onto NPDES, state, or city reports directly?	yes	yes	yes	yes
Highlights values that exceed NPDES limits?	Reports highlight calculated values that have exceeded NPDES limits.	If a parameter exceeds specified limits, the screen highlights the value to alert the user that a problem is occurring.	N/A	The screen will highlight values that exceed the specified NPDES limits.

Capability or Feature	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham, & Richardson	Cochrane, Inc.
Data Plotting: Tables, Graphs available?	Will generate graphic or table form of plot data. A variable vs. time per page may be done. Variables vs. variable may also be generated. Both scatter and line plots may be generated.	Summarizes data of parameters onto tables and graphs form. Graphs may be done in bar plot or scatter graph format. A line plot may not be generated. Parameters may be plotted vs. time, with up to four graphs per page for two months daily data or five years monthly averages. This allows allows some visual comparison between parameters. No parameter verus parameter plot can be executed. Good headings on graph. The scale on the graph may be changed at any time.	Laboratory data and process performance reports may be generated in tabular form showing average minimum and maximum values for each parameter.	Data plotting is available for multiple-day moving averages for any parameter. One or two parameters may be generated vs. time showing 1 or 2 months by day, yearly, or monthly averages.
Shows a summary of all calculated parameters?	Available	Available	N/A	N/A
Statistical analysis	Limited statistical analysis is available showing maximum, minimum, and average for certain parameters.	Summary report includes statistical analysis, showing minimum, maximum, average, and standard deviation of all the key parameters listed.	Limited statistical analysis is available showing maximum, minimum, and average for certain parameters.	Statistical analysis incorporating correlation coefficient, coefficient of determination, multiple regression analysis, and other functions identifying related process parameters may be generated.
Trend forecasting	Trend analysis is performed, which helps to analyze the plant's previous performance.	EOS gives a trend forecast for certain parameters with a calculated confidence level.	N/A	N/A
Password security	Two passwords are used: one to review data and the other to input data.	No password is required. Data on the hard disk may not be changed after the data from the previous month has been stored a month. Daily data and the 30-day average data are transferred out to floppy disk every 2 years. A password is required to change this data.	Information not available.	Password prohibits the unauthorized altering of stored data.
Generates missing data report.	N/A	N/A	Generates a report showing all input data that is missing, along with the corresponding day.	N/A

Specialized Reports	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham, & Richardson	Cochrane, Inc.
Daily Operation Report	Generates daily operation report summarizing key parameters. Includes historical data from the previous week for a specific unit.	Generates daily operation report summarizing key parameters.	Generates daily laboratory data report summarizing key parameters.	Generates daily operation report summarizing key parameters.
Weekly Operation Report	Available	Available	N/A	N/A
Monthly Operation Report	Monthly reports list the daily values of parameters for a particular treatment unit and serve as historical records for the plant. Maximum, minimum, and average values are shown.	See Below	N/A	A monthly listing of all key parameters may be generated showing average, maximum, and minimum values for each.
Tabular Reports	N/A	These reports show the daily changes in values for each treatment unit, for up to seven parameters per page. Minimum, maximum, total and average are also shown for each parameter.	N/A	N/A
Flash Report	N/A	Summarizes averages and trends only for the most important process control and operational parameters. A warning is given on any parameter that is not within specified limits.	N/A	N/A
Summary Report	N/A	Database summary reports may be generated (plant flows, BOD, etc.), showing average, minimum, maximum, and standard deviation for related key parameters. A warning is given when the actual number of observations falls below an expected level.	N/A	N/A

Specialized Reports	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham, & Richardson	Cochrane, Inc.
Sludge Calculations	N/A	N/A	N/A	The sludge return rate is calculated and shown graphically.
Performance Summary	Performance summary for selected groups of pollutants may be listed daily or monthly at different locations throughout the plant.	N/A	N/A	N/A
Unit Process Reports.	N/A	Automatically generates a detailed summary of a specific unit process showing average, trend, forecast value and the confidence shown in the forecast for key parameters.	N/A	N/A

I. Preventive Maintenance	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Jentech
Preventive Maintenance (PM) Task Listing	Option I: Suboption 1—A listing of all PM that can be handled by the available manhours is generated. This report may be generated in three groupings. The PM task description is listed along with the time required and other pertinent information.	PM task listing shows all PM tasks that have been grouped by equipment and location.	A PM task description report is given showing task description, materials needed, priority, labor account, and estimated hours.	A PM listing may be generated showing all tasks that need to be completed for each piece of equipment.
PM Scheduling Summary Report	Option I: Suboption 2—This report lists the trade, available and required manhours, scheduled and backlogged hours, and totals for each category.	This report lists the PM that was to be performed that week, along with material cost, estimated and actual.	This report shows equipment number, last PM date, interval between PMs, priority, labor, and estimated hours.	N/A
PM Schedules/M.H.	Option I: Suboption 3—Daily maintenance schedules are printed out showing jobs that can be completed by the available manhours. This is broken down into specific trades and also describes the PM task in depth.	Daily maintenance schedules are printed out showing jobs that should be completed that day.	A listing of all PM that is not complete is generated.	Lists all PM tasks that need to be completed as the equipment run hours are updated.
Weekly Maintenance Forecast	Takes the inputted available manhours and schedules the work that should be able to be completed for the week.	Takes the inputted available manhours and schedules the work that can be completed for the week.	Takes the inputted available manhours and schedules the work that should be able to be completed for the week.	N/A
Estimated Manhour Requirements for Each Type of Repair.	Estimated manhours requirements are inputted by the user and are stored for each job. This is the value that the computer keeps stored for scheduling purposes.	Estimated manhour requirements are inputted by the user and are stored for each job. This is the value that the computer keeps stored for scheduling purposes.	N/A	N/A

I. Preventive Maintenance	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Jentech
PM Backlogged Available?	Option I: Suboption 4--This report lists all PM tasks that are back-logged for each trade. The format is the same as the PM schedule report.	N/A	N/A	N/A
Capability To Reassign Priorities for Job Backlog?	Job priority is assigned by taking the elapsed time since the maintenance task was last performed by the recommended frequency. Priority is changed as jobs are completed and the old jobs are automatically rescheduled.	Jobs are assigned priorities (1-4) and are not changed as other jobs are inputted. A job assigned priority 1 will always be scheduled ahead of a priority 2 job.	Jobs are given a priority number as they are entered and the program will reassign jobs in accordance with the new entries.	N/A
Preventive Maintenance Work Order (WO) Assignments Printed Out?	Option I: Suboption 5—WO assignments are printed out, giving unit, components, location, priority, problem. The WO must then be filled out manually by the maintenance personnel, showing the work done and materials used.	WO assignments are printed out, showing the date of origin, age, equipment name, location, description of job or problem, and status.	N/A	N/A
PM Performed Report	Option I: Suboption 6—This report lists all the PM that has been performed for any time period specified by the user.	N/A	This report shows all the PM that has been completed on a piece of equipment, including the actual MH's needed and may be generated by location or labor class.	N/A
12-Month PM Labor Forecast.	Currently under review.	N/A	Twelve-month PM labor forecast may be generated based on the PM information stored.	N/A

	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Jentech
II. Equipment Run Time	Option II This option allows the user to change units online/off-line status. Either calendar days and/or run hours may be inputted.	Equipment run time may be entered either using calendar days and/or run hours may be inputted.	Equipment run time may be entered either using calendar days and/or run hours may be inputted.	Equipment run time may be entered either using calendar days, and/or run hours may be inputted.
III. Corrective Maintenance	Option III: Suboption 2— This is a report listing all CM performed for a specified period. It includes material and labor costs along with a repair description.	This report shows the complete-date, age, equipment name, and number, description, cause of problem, total time, and material cost.	This is grouped together with the PM as the equipment history.	Corrective maintenance for each piece of equipment may be printed, showing the history of each piece of equipment
CM WO printed out?	Option III: Suboption 3. This report shows the problem, the down-time and the job priority. It allows a space for identification of work performed and materials used for the crew to fill out manually.	This report shows the work that needs to be completed along with other pertinent information, including a listing of the 10 most recent jobs performed on that piece of equipment as background information.	N/A	N/A
Open Work Order Summary Report	N/A	This report may be generated by either work order number or location and priority. This report shows all pertinent information including priority and date of origin.	N/A	N/A
Closed Work Order Summary Report	N/A	Shows all detail maintained on a work order that has been completed including both the origin and completing dates.	N/A	CM completed is shown for each piece of equipment.
Closed Work Order	N/A	Shows priority, dates of origin and completion, work description, and other pertinent information.	Acknowledgement report is generated for completed maintenance tasks.	N/A

IV. Equipment Reports	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Jentech
Record, Serial Number	Option IV: Suboption 1-- A list of all equipment with the corresponding serial number is kept. May be generated by either component, model or unit identification.	A list of all equipment with the corresponding serial number is kept.	A list of all equipment with the corresponding serial number may be generated by vendor, manufacturer, location, and eqiupment type. A valuation report may be also be generated.	A list of all equipment with the serial number is kept.
Description	A description of the equipment is kept.	A description of the eqiupment is available on the screen and a hardcopy may be obtained.	A description of the eqiupment, including voltage, horsepower, or other pertinent performance data is kept.	A minor description is given in the manufacturer's information sheet.
Manufacturer Information	Manufacturer and vendor information, including; address, telephone number, and the number of parts supplied.	Manufacturer and vendor information including; address, telephone number, and point of contact.	Manufacturer and vendor information, including address, telephone number, point of contact, and financial data.	Manufacturer and vendor information, including address, telephone number and point of contact.
History Report	Option IV: Suboption 3-- All PM and CM may be printed by component, unit, or model identification for any date inputted showing the total maintenance performed.	Shows the CM performed by location, including purchase cost of equipment, year, and life totals for: WOs, CM MHs and material cost.	Work order history is printing showing the work that has been performed on a certain piece of eqiupment for a given time period.	A listing of the CM that has been performed may be generated for any component.
Repair Cost Report	Option IV: Suboption 4-- This report may be generated in three ways and breaks down the maintenance into PM and CM. Individual cost for labor and material given along with the total maintenance cost.	A history for each piece of equipment may be generated showing work completed, total cost, total hours, WO number, date completed, and location.	A history for each piece of equipment may be generated, showing work completed, cost, life expectancy, and depreciated value. This report may be generated by equipment type, location, manufacturer or vendor.	N/A
Repair Rate Report	Option IV: Suboption 5-- This shows the repair rate per 10,000 hours and may be generated for component or model identification.	N/A	N/A	N/A
Outstanding CM WO	Option IV: Suboption 7-- Shows all CM WO's that not yet been completed.	A backlog of open work orders is kept showing all that have not been completed. Included in this report are the total estimated hours needed to complete the jobs. Target values are also given for each category.	N/A	N/A

V. Inventory	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Jentech
Contents, value, parts usage, reorder needs.	Item number, description and storage location. Issues an inventory reorder report when a minimum level is exceeded. The CM is integrated with the inventory; when parts are inputted as being used to perform a job, the inventory is automatically reduced.	Maintains parts, vendor, and cost information. Reports inventory contents value, parts usage, and reorder needs.	Item number, description, and storage location. Quantity data, item on hand, reorder level, and quantity on order. May be generated.	Inventory *maintains* the part description, location, stock quantity, reorder point and unit cost. When the number of parts goes beneath minimum quantity, an inventory reorder form will be generated when requested, listing all parts that need to be reordered.
Status Report and Activity Report	Option IV: Suboptions 8b, 8c—The status report shows the inventory items along with all pertinent information. The activity report shows all transactions that occur involving inventory, and may be generated for any dates.	N/A	N/A	N/A
Value Report	Option IV: Suboption 8d—Lists all inventory and its current, average and last order cost.	List all parts by either stock number, storage location, equipment group or vendor ID and shows all pertinent information, including quantity, average cost, and inventory value.	*Gives item description*, storage location, number on hand, reorder point, number on order, unit cost, total value of each item, use, and the number used for the year.	*The value of each part may be* obtained in the inventory report.
Model Cross-Reference Report	Option IV: Suboption 8f—This report lists all inventory by either model or parts cross-reference.	N/A	N/A	N/A
Reorder Report	Option IV: Suboption 8h.—This report shows the number of parts that are below the minimum stock quantity and need to be ordered.	N/A	Shows the number of parts that are below the minimum stock quantity and need to be ordered.	Shows the number of parts that are below the minimum stock quantity and need to be ordered.
Parts *on* Order Report	Option IV: Suboption 8i--This report shows all parts that are currently on order.	*This report shows all parts* that are currently on order.	This reports shows all inventory that is currently on order, but does not show the date the order was placed.	N/A

VI. Other Maintenance	Metcalf & Eddy	Envirotech Operating Service	Henningson, Durham & Richardson	Jentech
Financial Data, Price, Life Expectancy, Depreciated Value	N/A	N/A	Unit cost, life expectancy, and depreciated value may all be inputted.	N/A
Usage Clarification (Operation, Maintenance Laboratory, General Facility)	N/A	N/A	Each part used is broken down into the segment where it was used (i.e., operation, maintenance, laboratory, general facility).	
Maintenance Flash Report	N/A	This report shows the time distribution, work order summary, cost summary and delinquent PM for all individual crafts. Should help to evaluate the productivity for for each craft.	N/A	N/A
Last Order Report	Option IV: Suboption 8j—This shows the last parts that were ordered and also whether the order has been completed.	N/A	N/A	N/A
End of Month Inventory Report	The inventory at the end of the month may be generated, showing previous and current supplies.	An inventory report may be generated at any time, but a comparison between the first and last of the month would have to be made manually by the user.	An end-of-month inventory may be generated showing all inventory currently in stock and all inventory that was used for the previous month.	An end-of-month inventory may be generated showing all inventory currently in stock. This would be manually compared with the previous month's final inventory report.

USA-CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-IMS-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

FESA, ATTN: Library 22060
ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library (41)

US Army Engineer Divisions
ATTN: Library (14)

US Army Europe
AEAEN-ODCS/Engr 09403
ISAE 09081
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (15)
21st Support Command
ATTN: DEH (12)
USA Berlin
ATTN: DEH (11)
USASETAF
ATTN: DEH (10)
Allied Command Europe (ACE)
ATTN: DEH (3)

8th USA, Korea (19)

USA Japan (USARJ)
ATTN: AJEN-DEH 96343
ATTN: DEH-Honshu 96343
ATTN: DEH-Okinawa 96331

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10966
ATTN: Facilities Engineer
ATTN: Dept of Geography & Computer Science
ATTN: DSCPER/MAEN-A

AMMRC, ATTN DRXMR-WE 02172

USA ARRCOM 61299
ATTN: DRCIS-RI-I
ATTN: DRSAR-IS

AMC - Dir., Inst., & Servc
ATTN: DEH (23)

DLA ATTN: DLA-WI 22314

DNA ATTN: NADS 20305

FORSCOM
FORSCOM Engr, ATTN: AFEN-DEH
ATTN: DEH (23)

HSC
ATTN: HSLO-F 78234
ATTN: Facilities Engineer
Fitzsimons AMC 80240
Walter Reed AMC 20012

INSCOM - Ch, Instl. Div
ATTN: Facilities Engineer (3)

ROK/US Combined Forces Command 96301
ATTN: EUSA-HHC-CFC/Engr

MDW, ATTN: DEH (3)

MTMC
ATTN: MTMC-SA 20315
ATTN: Facilities Engineer (3)

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac. Div. 48090

TRADOC
HQ, TRADOC, ATTN: ATEN-DEH
ATTN: DEH (19)

TSARCOM, ATTN: STSAS-F 63120

USACC, ATTN: Facilities Engr (2)

WESTCOM
ATTN: DEH, Ft. Shafter 96858
ATTN: APEN-IM

SHAPE 09055
ATTN: Surv. Section, CCB-OPS
Infrastructure Branch, LANDA

HQ USEUCOM 09128
ATTN: ECJ 4/7-LOE

FORT BELVOIR, VA 22060 (7)
ATTN: Canadian Liaison Officer
ATTN: British Liaison Officer
ATTN: Australian Liaison Officer
ATTN: French Liaison Officer
ATTN: German Liaison Officer
ATTN: Water Resources Support Ctr
ATTN: Engr Studies Center
ATTN: Engr Topographic Lab.
ATTN: ATZA-DTE-SU
ATTN: ATZA-DTE-EM
ATTN: R&D Command

CRREL, ATTN: Library 03755

WES, ATTN: Library 39180

HQ, XVIII Airborn Corps
and Fort Bragg
ATTN: AFZA-FE-EE 28307

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

Chanute AFB, IL 61868
3345 CES/DE, Stop 27

Norton AFB, CA 92409
ATTN: AFRCE-MX/DEE

AFESC, Tyndall AFB, FL 32403

NAVFAC
ATTN: Engineering Command (7)
ATTN: Division Offices (6)
ATTN: Naval Public Works Center (9)
ATTN: Naval Civil Engr Lab. (3)

ATTN: Library, Code L08A NCEL 93043

Defense Technical Info. Center 22314
ATTN: DDA (2)

Engr Societies Library, NY 10017

Natl Guard Bureau Instl. Div 20310

US Govt Print Office 22304
Receiving Sect/Depository Copies (2)

US Army Env. Hygiene Agency
ATTN: HSHB-E 21010

National Bureau of Standards 20899

ENE Team Distribution

Chief of Engineers
ATTN: DAEN-ZCF-B
ATTN: DAEN-ZCF-U
ATTN: DAEN-ECZ-A

US Army Engineer District
New York 10007
ATTN: Chief, NANEN-E
ATTN: Chief, Design Br.
Pittsburgh 15222
ATTN: Chief, Engr Div
Philadelphia 19106
ATTN: Chief, NAPEN-E
Norfolk 23510
ATTN: Chief, NAOEN-D
Huntington 25721
ATTN: Chief, ORHED-H
Wilmington 28401
ATTN: Chief, SAWEN-PM
ATTN: Chief, SAWEN-E
Charleston 29402
ATTN: Chief, Engr Div
Savannah 31402
ATTN: Chief, SASAS-L
Jacksonville 32232
ATTN: Env Res Br
Mobile 36628
ATTN: Chief, SAMEN-C
Vicksburg 39180
ATTN: Chief, Engr Div
Louisville 40201
ATTN: Chief, Engr Div
St. Paul 55101
ATTN: Chief, ED-H
Chicago 60604
ATTN: Chief, NCCCO-R
ATTN: Chief, NCCED-H
ATTN: Chief, NCCPD-ER
ATTN: Chief, NCCPE-PES
St. Louis 63101
ATTN: Chief, ED-P
ATTN: Chief, ED-D
Kansas City 64106
ATTN: Chief, Engr Div
Omaha 68102
ATTN: Chief, Engr Div
Little Rock 72203
ATTN: Chief, Engr Div
Tulsa 74102
ATTN: Chief, Engr Div
Fort Worth 76102
ATTN: Chief, SWFED-D
ATTN: Chief, SWFED-MA/MR
Galveston 77550
ATTN: Chief, SWGAS-L
ATTN: Chief, SWCCO-M
Los Angeles 90053
ATTN: Chief, SPLED-E
San Francisco 94105
ATTN: Chief, Engr Div
Sacramento 95814
ATTN: Chief, SPKED-D
Far East 96301
ATTN: Chief, Engr Div
Seattle 98124
ATTN: Chief, NPSEN-FM
ATTN: Chief, EN-DB-SE
ATTN: Chief, NPSEN-PL-WC
ATTN: Chief, NPSEN-PL-ER
Walla Walla 99362
ATTN: Chief, Engr Div
Alaska 99501
ATTN: Chief, NPASA-R

US Army Engineer Division
New England 02154
ATTN: Chief, NADEN-T
North Atlantic 10007
ATTN: Chief, NADEN-T
Middle East (Rear) 22601
ATTN: Chief, MEDED-T
South Atlantic 30303
ATTN: Chief, SADEN-TE

US Army Engineer Division
Huntsville 35807
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-ME
ATTN: Chief, HNDED-SR
Lower Mississippi Valley 39180
ATTN: Chief, PD-R
Ohio River 45201
ATTN: Chief, Engr Div
North Central 60605
ATTN: Chief, Engr Planning Br
Missouri River 68101
ATTN: Chief, MRDED-T
Southwestern 75242
ATTN: Chief, SWDED-TH
North Pacific 97208
ATTN: Chief, Engr Div.
South Pacific 94111
ATTN: Chief, SPDED-TG
ATTN: Laboratory
Pacific Ocean 96858
ATTN: Chief, Engr Div
ATTN: Chief, PODED-MP
ATTN: Chief, PODED-P

5th US Army 78234
ATTN: AFKB-LG-E

6th US Army 94129
ATTN: AFKC-EN

7th US Army 09407
ATTN: AETTM-HRD-EHD

10th Medical Laboratory
APO NEW YORK 09180

US Army Foreign Science & Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office 96328

USA ARRADCOM
ATTN: DRDAR-LCA-OK 07801

West Point, NY 10996
ATTN: Dept of Mechanics
ATTN: Library

Ft. Belvoir, VA 22060
ATTN: Learning Resources Center
ATTN: ATSE-TD-TL (2)

Ft. Clayton Canal Zone 34004
ATTN: DFAE

Ft. A. P. Hill 24502
ATTN: FE

Ft. Leavenworth, KS 66027
ATTN: ATZLCA-SA

Ft. Lee, VA 23801
ATTN: DRXMC-D (2)

Ft. McPherson, GA 30330
ATTN: AFEN-CD

Ft. Monroe, VA 23651
ATTN: ATEN-AD (3)
ATTN: ATEN-FE-E
ATTN: ATEN-FE-U
Aberdeen Proving Ground. MD 21005
ATTN: AMXHE
ATTN: HSE-EW
ATTN: OAC-ARI-E

Naval Facilities Engr Command 22332
ATTN: Code 04

US Naval Oceanographic Office 39522
ATTN: Library

Naval Training Equipment Center 32813
ATTN: Technical Library

Bolling AFB, DC 20330
AF/LEEEU

Little Rock AFB
ATTN: 314/DEEE

Patrick AFB, FL 32925
ATTN: XRQ

Tinker AFB, OK 73145
2854 ABG/DEEE

Tyndall AFB, FL 32403
AFESC/PRT

Bldg Research Advisory Board 20418

Dept of Transportation
Talahassee, FL 32304

Dept of Transportation Library 20590

Transportation Research Board 20418

Airports and Construction Services Dir
Ottawa, Ontario, Canada K1A ON8

Division of Building Research
Ottawa, Ontario, Canada K1A OR6

National Defense Headquarters
Ottawa, Ontario, Canada K1A OK2

105
01/86

END